

PROCEEDING



12th International Conference on Creative Technology



CreTech²⁰²⁶

Multidisciplinary

Perspectives on Community-Centered
Technology for Sustainability

August 6 - 8 , 2026

Grand Palazzo Hotel Pattaya, Chonburi Province, Thailand

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สมาคมวิศวกรรมและเทคโนโลยีสารสนเทศ ร่วมกับ มหาวิทยาลัยเทคโนโลยีราชมงคลกรุงเทพ

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การประชุมวิชาการอำนวยการเพื่อพัฒนาเทคโนโลยีสำหรับชุมชนสู่ความยั่งยืน
6-8 สิงหาคม 2569 (โรงแรมแกรนด์ พาลาซโซ่ พัทยา จังหวัดชลบุรี)

Welcome Message

The 11th National Conference on Creative Technology and the 12th International Conference on Creative Technology (CreTech2026) will be held on 6–8 August 2026 at the Grand Palazzo Hotel, Pattaya, Chonburi, Thailand, under the theme “Multidisciplinary Perspectives on Community-Centered Technology for Sustainability.” CreTech2026 brings together researchers, academics, professionals, and students to share knowledge, exchange ideas, and present creative research and innovations for a sustainable future.

Beyond the conference, Pattaya and Chonburi offer a vibrant coastal experience with beautiful beaches, islands, local cuisine, and renowned attractions such as the Sanctuary of Truth and Nong Nooch Tropical Garden, providing participants with an opportunity to experience the culture and hospitality of Thailand’s eastern coast.

On behalf of the Organizing Committee, we sincerely thank all keynote speakers, authors, reviewers, partners, and participants for their valuable contributions.

We warmly welcome you to CreTech2026 and Pattaya, Thailand, and wish you an inspiring, productive, and memorable experience.



สมาคมนวัตกรรมและเทคโนโลยีสร้างสรรค์ ร่วมกับ มหาวิทยาลัยเทคโนโลยีราชมงคลกรุงเทพ

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Message from the ICTA President

On behalf of the Innovation and Creative Technology Association (ICTA), it is my great pleasure to welcome you to the 11th National Conference on Creative Technology and the 12th International Conference on Creative Technology (CreTech2026), held during 6–8 August 2026 at the Grand Palazzo Hotel, Pattaya, Chonburi, Thailand.

Under the theme “Multidisciplinary Perspectives on Community-Centered Technology for Sustainability,” CreTech2026 provides a platform for researchers, academics, professionals, and students to share knowledge, present innovative research, and strengthen multidisciplinary collaboration toward sustainable community and societal development.

I would like to express my sincere appreciation to all committee members, reviewers, researchers, partner institutions, and participants for their valuable contributions. I hope CreTech2026 will inspire new ideas, meaningful collaborations, and innovations that create lasting benefits for society and the future.

Asst. Prof. Chaiyasak Klaidaeng

President, Innovation and Creative Technology Association (ICTA)



สมาคมวิศวกรรมและเทคโนโลยีสร้างสรรค์ ร่วมกับ มหาวิทยาลัยเทคโนโลยีราชมงคลกรุงเทพ

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Message from the RMUTK President

It is my great pleasure to welcome all participants to the 11th National Conference on Creative Technology and the 12th International Conference on Creative Technology (CreTech2026), held during 6–8 August 2026 at the Grand Palazzo Hotel, Pattaya, Chonburi, Thailand.

Under the theme “Multidisciplinary Perspectives on Community-Centered Technology for Sustainability,” CreTech2026 provides an important platform for researchers, academics, professionals, and students to present their research, exchange knowledge and ideas, and build multidisciplinary collaborations. We believe that integrating creativity, technology, and diverse perspectives can lead to meaningful innovations that respond to community needs and contribute to sustainable development.

On behalf of Rajamangala University of Technology Krungthep, I would like to express my sincere appreciation to the Innovation and Creative Technology Association, partner institutions, organizing committees, reviewers, authors, and all participants for their valuable contributions to CreTech2026.

I wish all participants a productive and inspiring conference and hope that CreTech2026 will foster new knowledge, strong academic networks, and collaborations that create lasting benefits for society.

Assoc. Prof. Dr. Pichai Janmanee

President

Rajamangala University of Technology Krungthep



สมาคมวิศวกรรมและเทคโนโลยีสารสนเทศ ร่วมกับ มหาวิทยาลัยเทคโนโลยีราชมงคลกรุงเทพ

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Message from the Vice President

It is my great pleasure to welcome you to the 11th National Conference on Creative Technology and the 12th International Conference on Creative Technology (CreTech2026), held during 6–8 August 2026 at the Grand Palazzo Hotel, Pattaya, Chonburi, Thailand.

Under the theme “Multidisciplinary Perspectives on Community-Centered Technology for Sustainability,” CreTech2026 brings together researchers, academics, professionals, and students from diverse disciplines to share knowledge, exchange ideas, and explore how creativity and technology can contribute to sustainable communities and society.

The conference provides an important platform for multidisciplinary research, academic exchange, and professional networking. We hope these interactions will inspire new ideas, meaningful collaborations, and practical innovations that create lasting benefits beyond the conference.

On behalf of Rajamangala University of Technology Krungthep, I would like to express my sincere appreciation to all authors, reviewers, keynote speakers, organizing committee members, partner institutions, and participants for their valuable contributions and support.

I wish you a productive and inspiring conference and a memorable stay in Pattaya, Chonburi, Thailand.

Asst. Prof. Dr. Saichol Chudjuarjeen

Vice President

Rajamangala University of Technology Krungthep

Conference Topics

Track 1: Engineering and Technology

- 1.1 Mechanical and Aerospace Engineering
- 1.2 Civil, Surveying and Infrastructure Engineering
- 1.3 Industrial Engineering and Manufacturing Systems
- 1.4 Chemical and Process Engineering
- 1.5 Electrical, Electronics and Intelligent Systems Engineering
- 1.6 Digital, Computer and Internet of Things (IoT) Engineering
- 1.7 Other Related Fields

Track 2: Science, Technology and Creative Innovation

- 2.1 Biological Sciences, Health and Beauty
- 2.2 Food Science, Food Safety and Food Biotechnology
- 2.3 Energy Technology, Environment and Sustainability
- 2.4 Artificial Intelligence, Data Science and Computational Technology
- 2.5 Chemical Sciences, Analytical Science and Applied Materials
- 2.6 Creative Technology, Digital Design and Product Innovation
- 2.7 Other Related Fields

Track 3: Business, Tourism and Economics

- 3.1 Finance, Accounting, and Valuation
- 3.2 Business Management and Human Resource Management
- 3.3 Marketing, International Trade and Logistics
- 3.4 Digital Business and Information Systems
- 3.5 Entrepreneurship and Startups
- 3.6 Service Business, Tourism and Aviation Management
- 3.7 Other Related Fields

Track 4: Social Sciences, Humanities, Language and Community Development

- 4.1 Consumer Behavior and Social Trends
- 4.2 Aging Society, Well-being and Quality of Life
- 4.3 Language and Communication
- 4.4 Culture, Local Wisdom and Social Capital
- 4.5 Community Development, Social Innovation and Lifelong Learning
- 4.6 Public Policy, Governance and Sustainable Development
- 4.7 Other Related Fields



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Track 5: Educational Innovation and STEM

- 5.1 Learning Innovation and Pedagogical Design
- 5.2 Educational Technology and Digital Learning Systems
- 5.3 STEM Education and Applied Learning
- 5.4 Curriculum Development and Instructional Design
- 5.5 Educational Measurement, Assessment and Evaluation
- 5.6 Lifelong Learning and Human Capital Development
- 5.7 Other Related Fields

Track 6: Law, Medicine, and the Health Industry

- 6.1 Law, Public Policy, and Governance
- 6.2 Medical Innovation, Health Technologies, and Digital Health
- 6.3 Health Industry and Medical Devices
- 6.4 Interdisciplinary Health Studies



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CreTech2026 Program at a Glance

Venue: Grand Palazzo Hotel Pattaya, Chonburi, Thailand

Thursday, 6 August 2026

14:00 — Open Registration

14:00–17:30 — ICTA and Network

Friday, 7 August 2026

08:00 — Open Registration

08:00–11:50 — Morning Sessions

09:00–09:30 — Opening Ceremony

09:30–10:00 — Keynote Session

10:00–10:15 — Break

10:15–11:05 — International Keynote Sessions

13:00–14:40 — Parallel Oral Presentation Sessions

14:40–14:50 — Session Break

14:40–16:00 — Afternoon Parallel Oral Presentation Sessions

16:00 — Session Break

Saturday, 8 August 2026

09:00–10:40 — Parallel Oral Presentation Sessions

10:40–10:50 — Session Break

12:00–13:00 — Lunch

13:30–16:00 — Researcher Networking

16:00 — End of Conference

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Influence of SLA Printing Parameters on the Mechanical Performance and Printing Efficiency of Dental Photopolymer Resin

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ABSTRACT

Stereolithography (SLA) is widely used in dental additive manufacturing due to its high dimensional accuracy, good surface finish, and ability to fabricate customized complex geometries. However, the performance of SLA-printed dental components is strongly influenced by printing parameters, particularly layer thickness and build orientation. This study investigated the effects of layer thickness and build orientation on the printing efficiency, dimensional accuracy, and tensile properties of dental photopolymer resin fabricated using SLA technology. Tensile specimens were printed using three-layer thicknesses of 25, 50, and 100 μm and three build orientations: perpendicular, vertical, and horizontal. Printing time, resin consumption, dimensional error, ultimate tensile strength (UTS), and Young's modulus were evaluated. The results showed that decreasing the layer thickness increased printing time due to the higher number of printed layers and repeated curing/separation cycles, while resin consumption was mainly affected by build orientation and support structure. Dimensional accuracy was orientation-dependent, with vertical specimens showing higher width error and horizontal specimens showing higher thickness error. For tensile properties, the highest strength and stiffness were obtained from the specimen printed with 50 μm layer thickness in the vertical orientation, which showed the highest UTS of 60.42 N/mm² and Young's modulus of 818.04 N/mm². This improvement was attributed to more effective tensile force transfer along the loading direction. Overall, the 100 μm layer thickness is suitable for reducing printing time, while the 50 μm vertical condition is recommended for improving the strength and stiffness of SLA-printed dental photopolymer resin.

Keywords: SLA, dental photopolymer resin, tensile properties, layer thickness, build orientation, additive manufacturing

1. INTRODUCTION

Additive manufacturing technologies have gained significant attention in dental applications due to their capability to

fabricate customized components with high precision and complex geometries. Among these technologies, stereolithography (SLA) is widely used because of its excellent surface finish, fine resolution, and ability to produce

highly detailed dental structures such as surgical guides, orthodontic appliances, and temporary restorations [1].

SLA technology operates through the layer-by-layer photopolymerization of liquid resin using ultraviolet (UV) light. The mechanical performance of SLA-printed components is strongly influenced by process parameters, particularly layer thickness and build orientation. Layer thickness affects interlayer bonding and printing resolution, while build orientation influences stress transfer behavior and anisotropic mechanical properties during tensile loading [2]. Previous studies reported that stereolithography-fabricated polymers exhibit directional dependence in tensile properties due to layer stacking orientation and curing strategy [3]. However, limited studies have focused specifically on the influence of SLA printing parameters on dental photopolymer resin.

Therefore, this study aims to investigate the influence of layer thickness and build orientation on the mechanical performance of dental photopolymer resin fabricated using SLA technology.

2. MATERIALS AND METHODS

2.1 Photopolymer Resin

The material used in this study was a commercial dental photopolymer resin obtained from Formlabs. The resin is primarily composed of acrylate monomers, acrylate oligomers, and photoinitiators, which are suitable for stereolithography (SLA) additive manufacturing processes. The

photopolymer resin was used as the printing material for fabrication of all tensile test specimens. The mechanical properties of the photopolymer resin provided by the manufacturer are summarized in Table 1.

Table 1. Mechanical properties of Photopolymer resin dental model [4]

Properties	Values
Tensile strength	61 N/mm ²
Elongation at break	5 %
Elastic modulus	2,500 N/mm ²
Flexural strength	95.8 N/mm ²
Flexural modulus	2,300 N/mm ²

2.2 SLA and processing parameters

The tensile test specimens were designed according to ASTM D638 standard using computer-aided design (CAD) software and exported in STL format for printing preparation. The specimens were fabricated using a commercial stereolithography (SLA) 3D printer (Formlabs 3) as shown in Fig1.

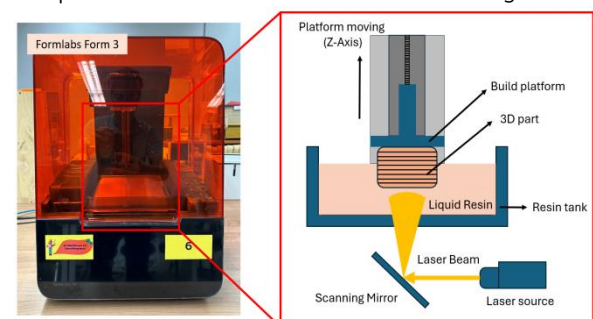


Figure 1. Formlabs Form 3 3D printer and the stereolithography process

The influence of SLA printing parameters on the mechanical performance of dental photopolymer resin was investigated using two primary process parameters layer thickness and build

orientation. Three levels of layer thickness were selected, consisting of 25 μm , 50 μm , and 100 μm . In addition, three different build orientations were investigated, including perpendicular, vertical, and horizontal orientations. A total of nine experimental conditions were designed, with three replicates for each condition, as summarized in Table 2.

Table 2. SLA processing parameters used in this study

Sample	Layer Thickness	Build Orientation
S1	100 μm	Perpendicular
S2		Vertical
S3		Horizontal
S4	50 μm	Perpendicular
S5		Vertical
S6		Horizontal
S7	25 μm	Perpendicular
S8		Vertical
S9		Horizontal

After fabrication, all printed specimens were cleaned using isopropyl alcohol (IPA) to remove uncured resin from the surface and subsequently post-cured under ultraviolet (UV) light according to the manufacturer's recommendations to ensure complete polymerization prior to tensile testing.

2.3 Printing Efficiency Measurement

Dimensional accuracy was evaluated by measuring the width and thickness of the printed specimens using a digital Vernier caliper. The measured values were compared with the designed CAD dimensions, and the percentage error was calculated. Printing time and resin consumption were obtained directly from the slicing software based on the selected layer thickness, build orientation.

2.4 Mechanical Properties Testing

To evaluate the mechanical behavior of the SLA-printed dental photopolymer resin, tensile tests were performed using a QC-506M1 universal testing machine at room temperature. The specimens were prepared in accordance with the ASTM D638-14 standard (Type IV geometry), and the crosshead speed was set to 5 mm/min. The tensile strength, and Young's modulus were recorded for all samples to evaluate the influence of SLA printing parameters on the mechanical performance of the fabricated specimens. Experimental setup for tensile testing is shown in Fig2.

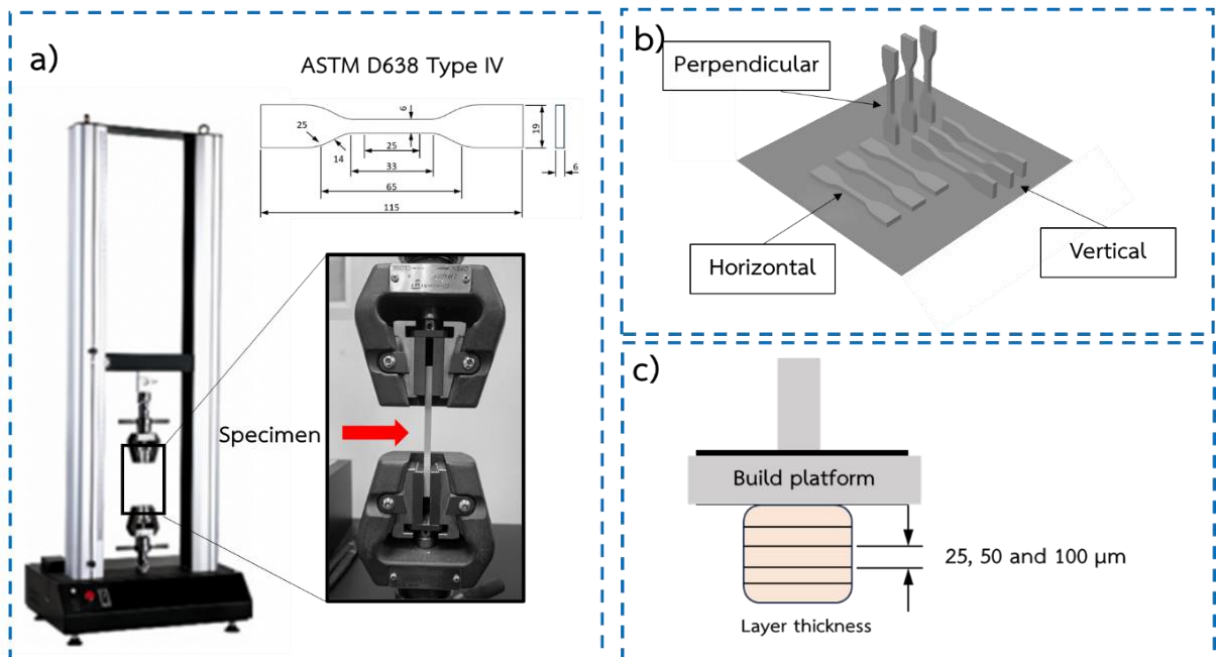


Figure 2. a) Experimental setup for tensile testing and schematic illustration of b) build orientations and c) Layer Thickness SLA-printed parameter

3. RESULTS AND DISCUSSION

3.1 Printing Time and Resin Consumption

The printing efficiency results showed that layer thickness strongly affected printing time. The 25 μm layer thickness required the longest printing time because it increased the number of printed layers and repeated curing/separation cycles, as shown in Fig. 3. In contrast, the 100 μm layer thickness provided the shortest printing time due to the lower number of layers. Resin consumption was mainly influenced by build orientation. Specimens printed in orientations requiring more support consumed more resin, even though the specimen geometry was identical. Therefore, reducing layer thickness increased printing time, while build orientation mainly controlled resin consumption.

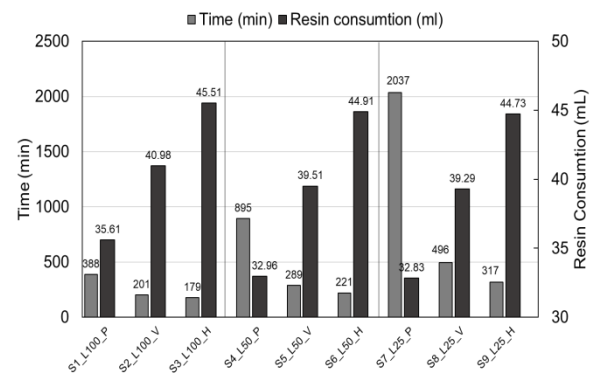


Figure 3. Printing time and resin consumption of SLA-printed dental resin specimens with different parameters

3.2 Dimensional Accuracy

Dimensional error influenced by adhesion force during the layer separation process. According to Stefan adhesion [5], a larger contact area between the cured layer and the window can generate a higher separation force. This repeated pulling force during printing slightly deforms the specimen in the direction associated with the build

orientation or larger projected area [6]. This explanation agrees with the present results, where the Vertical orientation showed higher width error, while the Horizontal orientation showed higher thickness error, as illustrated in Fig. 4. Therefore, the dimensional deviation of SLA-printed dental resin specimens was orientation-dependent [6], and the dimension affected by layer separation force tended to show error.

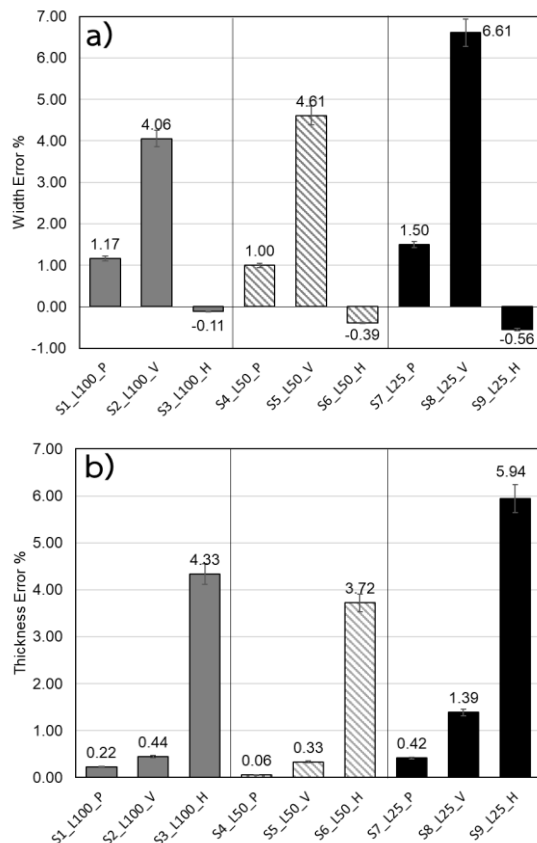


Figure 4. Dimensional accuracy of SLA-printed dental resin specimens fabricated with different parameters (a) width error % and (b) thickness error%

3.3 Effect of SLA Parameter on Ultimate Tensile Strength (UTS) and Young's modulus

The highest UTS was obtained from S5 (60.42 N/mm²). A similar trend was observed for Young's modulus, where S5 also showed the highest value of 818.04 N/mm², as illustrated in Fig. 5. This suggests that the 50 μ m layer thickness with Vertical orientation provided the best combination of strength and stiffness. This improvement can be attributed to the ability of the Vertical orientation to absorb and transfer tensile force more effectively along the loading direction, thereby increasing resistance to deformation and crack propagation [7].

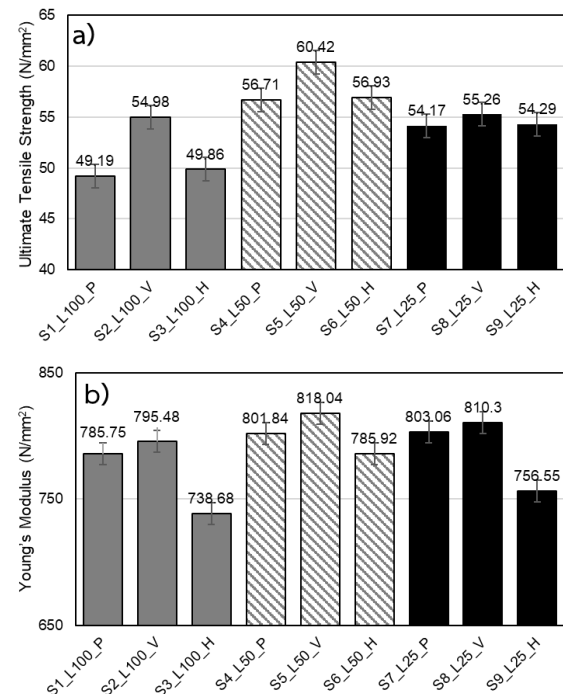


Figure 5. Tensile properties of SLA-printed dental resin specimens fabricated with difference parameters (a) ultimate tensile strength and (b) Young's modulus

4. CONCLUSIONS

This study investigated the influence of layer thickness and build orientation on the printing efficiency, dimensional accuracy,

and tensile properties of SLA-printed dental photopolymer resin. The key findings are:

Decreasing the layer thickness increased the printing time. Therefore, the 25 μm condition required the longest printing time, while the 100 μm condition provided the shortest printing time. Resin consumption was mainly influenced by build orientation due to the different support structure requirements.

Dimensional accuracy was dependent on orientation. The Vertical orientation resulted in higher width error, whereas the Horizontal orientation resulted in higher thickness error.

For tensile properties, the best performance was obtained from S5, printed with 50 μm layer thickness and Vertical orientation, which showed the highest UTS of 60.42 N/mm² and Young's modulus of 818.04 N/mm². This was due to better force transfer along the loading direction, which improved strength and stiffness.

5. ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Research and Development Institute, Rajamangala University of Technology Krungthep (RMUTK), for financial support under the research grant (Grant No. R-69-038). The support provided for the research project entitled "Development of SLA 3D Printing Processes for Dental Model Fabrication" is gratefully acknowledged.

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Influence of a Reinforced Concrete Core-Wall System on the Seismic Response of a 10-Story Moment-Resisting Frame Building in Bangkok

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ABSTRACT

Bangkok is located in a region of low to moderate seismicity; however, the presence of thick soft-soil deposits may amplify earthquake ground motions from distant seismic sources and affect the response of reinforced concrete buildings. This study evaluates the influence of a reinforced concrete core-wall system on the seismic response of a 10-story reinforced concrete moment-resisting frame building in Bangkok. Two three-dimensional analytical models were developed using ETABS. Model 1 represents a conventional reinforced concrete moment-resisting frame building, while Model 2 represents the same building with an additional central reinforced concrete core-wall system. Both models had identical plan geometry, story height, material properties, gravity loading, and seismic design parameters. Response spectrum analysis was performed in accordance with DPT 1301/1302–2018. The comparison focused on fundamental period, base shear, story shear distribution, roof displacement, interstory drift, and the estimated lateral shear contribution of the core-wall system. The results show that the addition of the central core wall reduced the fundamental period from 2.013 s to 1.328 s, corresponding to a reduction of approximately 34.0%. The scaled seismic base shear increased slightly from 192.842 tonf to 194.589 tonf, or approximately 0.9%. In contrast, the roof displacement decreased from 141.7 mm to 75.2 mm, representing a reduction of approximately 46.9%. The maximum interstory drift ratio also decreased from 0.007038 to 0.003369, corresponding to a reduction of approximately 52.1%. Based on the pier force output at the base level, the central reinforced concrete core-wall system was estimated to contribute approximately 63.9% of the total lateral shear in Model 2. These results indicate that the central reinforced concrete core-wall system significantly improves lateral stiffness and drift control while causing only a minor increase in the design base shear.

Keywords: Reinforced Concrete Building, Reinforced Concrete Core-Wall System, Moment-Resisting Frame, Response Spectrum Analysis

1. INTRODUCTION

Bangkok is generally regarded as a region of low to moderate seismicity compared with areas located near major active faults. However, the seismic response of buildings in Bangkok cannot be neglected because the

city is underlain by deep alluvial deposits and thick soft-soil layers that can amplify earthquake ground motions generated by distant seismic sources [1–3]. Previous studies have reported that the Bangkok Basin can produce significant site and basin amplification effects, particularly in the long-period

range, which may influence the response of medium- and high-rise buildings in the Bangkok metropolitan area [2,3]. Therefore, seismic response evaluation of reinforced concrete buildings in Bangkok has become an important issue for structural engineering practice.

In Thailand, seismic design requirements for buildings are specified in the Thai seismic design standard DPT 1301/1302–2018, which provides procedures for determining earthquake effects on buildings and structures [4]. For regular buildings, response spectrum analysis is commonly used to evaluate modal characteristics, base shear, story shear distribution, lateral displacement, and interstory drift [4,5]. These response quantities are essential for understanding the overall lateral behavior of reinforced concrete buildings under earthquake loading and for comparing the effectiveness of different lateral-force-resisting systems.

Reinforced concrete moment-resisting frames are widely used in building construction because they provide architectural flexibility and resist gravity and lateral loads through beam-column action. However, for medium- to high-rise buildings, a frame-only system may result in relatively large lateral displacement and interstory drift when subjected to seismic excitation. In contrast, reinforced concrete core-wall systems are commonly introduced to increase lateral stiffness, reduce lateral displacement, and improve drift control. Previous studies on reinforced concrete shear wall and core-wall

buildings have shown that wall stiffness, cracking effects, and shear demand distribution can significantly influence the seismic response of buildings [6,7].

Although core-wall systems are commonly used in reinforced concrete buildings, their influence on the seismic response of mid-rise reinforced concrete buildings under the soft-soil conditions of Bangkok requires further clarification. In particular, a direct comparison between a conventional moment-resisting frame system and the same frame system with a central reinforced concrete core wall can provide useful insight into the role of the core-wall system in modifying lateral stiffness, force distribution, roof displacement, and interstory drift.

This study aims to evaluate the influence of a reinforced concrete core-wall system on the seismic response of a 10-story reinforced concrete moment-resisting frame building in Bangkok. Two three-dimensional analytical models were developed using ETABS. Model 1 represents a conventional reinforced concrete moment-resisting frame building, while Model 2 represents the same building with an additional central reinforced concrete core-wall system. Both models were assigned identical plan geometry, story height, material properties, gravity loading, and seismic design parameters to provide a consistent basis for comparison. The seismic response was evaluated using response spectrum analysis based on DPT 1301/1302–2018. The comparison focuses on fundamental period, modal mass participation, base shear,

story shear distribution, roof displacement, interstory drift, and the estimated lateral shear contribution of the core-wall system.

2. MATERIALS AND METHODS

2.1 BUILDING DESCRIPTION

A 10-story reinforced concrete building was selected as the prototype structure in this study. The building plan was 25 m × 25 m, consisting of five bays in each principal horizontal direction with a typical bay width of 5 m. The typical story height was 3.5 m, and the seismic height used in the analysis was 31.5 m. The building was assumed to have a regular plan and elevation configuration to provide a clear basis for comparing the influence of the reinforced concrete core-wall system. The structural member dimensions and stiffness modifiers used in this study followed the analytical modeling assumptions adopted in a previous study by Rattanavijit et al. [8].

The concrete compressive strength used for all reinforced concrete members was $f'_c = 280$ ksc. The beam section was 0.25 m × 0.50 m for all stories. The column sections were 0.70 m × 0.70 m for Floors 1–2, 0.60 m × 0.60 m for Floors 3–6, and 0.50 m × 0.50 m for Floors 7–Roof. The reinforced concrete slab thickness was 0.175 m and was modeled using thin shell elements. Rigid diaphragms were assigned at all floor levels.

Table 1. Main structural member properties.

Member	Dimension / property
Beam	0.25 m × 0.50 m
Column	0.70, 0.60, 0.50 m square sections
Slab	0.175 m thick

Member	Dimension / property
Core wall	5 m × 5 m, 0.25 m thick

Note; Concrete $f'_c = 280$ ksc

2.2 ANALYTICAL MODELS

Two three-dimensional analytical models were developed using ETABS. Model 1 represents a conventional reinforced concrete moment-resisting frame building, in which the lateral resistance was provided by the beam-column frame system. Model 2 represents the same moment-resisting frame building with an additional central reinforced concrete core-wall system. The core wall was placed at the center of the building plan to maintain structural symmetry in both principal directions and was continuous over the full building height. The plan layouts and three-dimensional analytical models of Model 1 and Model 2 are shown in Figure 1.

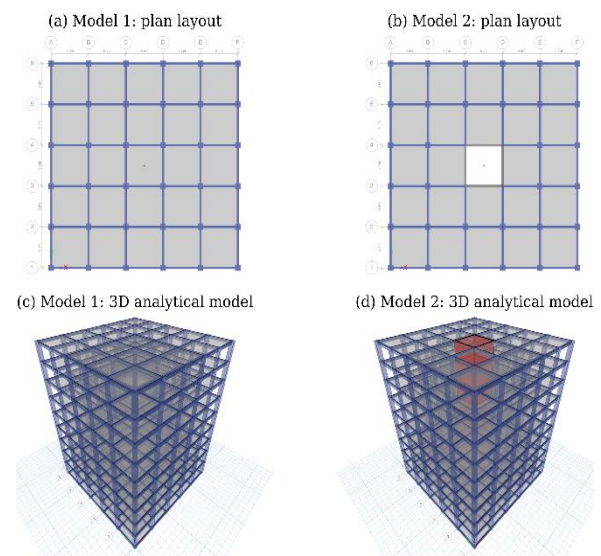


Figure 1. Analytical models: (a) Model 1 plan, (b) Model 2 plan, (c) Model 1 3D model, and (d) Model 2 3D model.

Frame elements were used to model beams and columns, while shell elements

were used to model the reinforced concrete slabs and the core-wall system. The same material properties, gravity loading, frame-member dimensions, slab thickness, and seismic design parameters were assigned to both models. Therefore, the primary difference between the two models was the presence of the central reinforced concrete core-wall system in Model 2.

Table 2. Description of the analytical models.

Model	Structural system
Model 1	Reinforced concrete moment-resisting frame
Model 2	Reinforced concrete moment-resisting frame with central reinforced concrete core wall

2.3 STIFFNESS MODIFIERS

Stiffness modifiers were assigned to represent the reduced stiffness of cracked reinforced concrete members under lateral loading. For beams, the moments of inertia about the local 2 and 3 axes were reduced to $0.35I_g$, while the torsional constant was kept as 1.00. For columns, the moments of inertia about the local 2 and 3 axes were reduced to $0.70I_g$, while the torsional constant was kept as 1.00. For slabs, the bending stiffness modifiers M_{11} , M_{22} , and M_{12} were taken as $0.25I_g$.

For the reinforced concrete core-wall system, the membrane stiffness modifiers F_{11} , F_{22} , and F_{12} were taken as 0.35, and the bending stiffness modifiers M_{11} , M_{22} , and M_{12} were also taken as 0.35. The transverse shear stiffness modifiers V_{13} and V_{23} were kept as 1.00. The mass and weight modifiers of the core-wall elements were kept as 1.00.

Table 3. Stiffness modifiers used in the analytical models.

Member	Main stiffness modifiers
Beam	$I_2, I_3 = 0.35I_g$, Torsion = 1.00
Column	$I_2, I_3 = 0.70I_g$, Torsion = 1.00
Slab	$M_{11}, M_{22}, M_{12} = 0.25I_g$
Core wall	Membrane, Bending = 0.35, Shear = 1.00

2.4 SEISMIC ANALYSIS PROCEDURE

The seismic response of the two models was evaluated using response spectrum analysis in accordance with the Thai seismic design standard DPT 1301/1302–2018 [4]. The design response spectrum was applied independently in the two principal horizontal directions of the building. The importance factor was taken as $I = 1.00$ for a standard occupancy building. The response modification factor and deflection amplification factor were taken as $R = 5.00$ and $C_d = 4.50$, respectively, for both models.

The modal participating mass ratios were checked to ensure sufficient modal contribution in each principal direction. The response-spectrum base shear was scaled to satisfy the minimum base shear requirement, in which the design base shear from response spectrum analysis should not be less than 85% of the equivalent lateral force base shear specified by the seismic design standard [4]. Force-related results were evaluated using the scaled response-spectrum load combinations. For displacement and inter-story drift evaluation, the response was adjusted using $C_d/R = 0.90$.

2.5 RESPONSE PARAMETERS

The seismic responses of Model 1 and Model 2 were compared using fundamental period, modal participating mass ratio, scaled seismic base shear, story shear distribution, roof displacement, and maximum interstory drift ratio. These parameters were selected because they directly represent the global lateral stiffness, force demand, displacement response, and drift performance of the structural system under seismic loading. In addition, the estimated lateral shear contribution of the central reinforced concrete core-wall system in Model 2 was evaluated using the pier force output at the base level. This value was used only as an estimated shear-sharing indicator because response spectrum analysis provides modal-combined design responses rather than exact simultaneous force distributions.

3. RESULTS AND DISCUSSION

3.1 MODAL CHARACTERISTICS

The modal analysis results indicate that the addition of the central reinforced concrete core-wall system significantly increased the lateral stiffness of the building. The fundamental period of Model 1 was 2.013 s, whereas the fundamental period of Model 2 was reduced to 1.328 s. This represents a reduction of approximately 34.0%. The shorter period of Model 2 indicates that the core-wall system increased the overall lateral stiffness of the building in both principal directions.

The cumulative modal participating mass ratios in the principal horizontal directions were greater than 0.98 for both models. Therefore, the number of modes used in the response spectrum analysis was sufficient to represent the global seismic response of the buildings. The modal results confirm that the comparison between the two models was based on adequate modal participation.

Table 4. Seismic response comparison.

Response parameter	Model 1	Model 2
Fundamental period (s)	2.013	1.328
Sum UX	0.9857	0.9895
Sum UY	0.9857	0.9895
Scaled base shear (tonf)	192.842	194.589
Roof displacement (mm)	141.7	75.2
Maximum interstory drift ratio	0.007038	0.003369

3.2 BASE SHEAR AND STORY SHEAR

The scaled seismic base shear of Model 1 was 192.842 tonf, while that of Model 2 was 194.589 tonf. The base shear increased by only approximately 0.9% after the core-wall system was added. This small increase was mainly related to the slightly higher seismic weight of Model 2 and the response spectrum scaling requirement. Although the core-wall system substantially increased the lateral stiffness of the building, the total design base shear did not increase significantly because both models were evaluated using the same seismic design parameters and the same response spectrum procedure.

The story shear distribution showed a similar increasing trend from the roof level

toward the lower stories for both models. However, Model 2 exhibited slightly higher story shear values than Model 1 at most story levels. This result is consistent with the increase in global lateral stiffness and the slight increase in the scaled base shear of Model 2. The comparison of story shear distribution is shown in Figure 2.

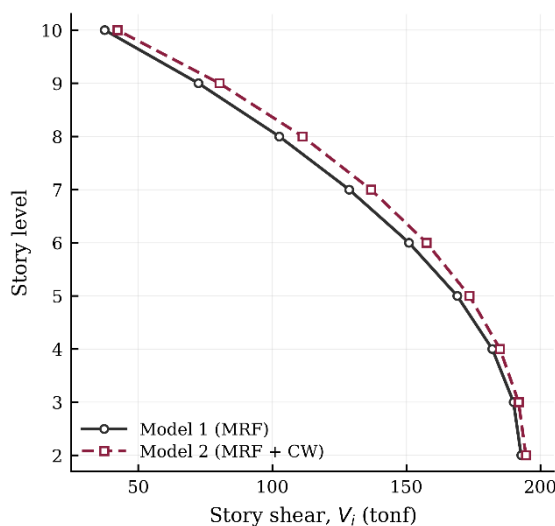


Figure 2. Story shear distribution of Model 1 and Model 2.

3.3 ROOF DISPLACEMENT

The roof displacement of Model 1 was 141.7 mm, whereas that of Model 2 was reduced to 75.2 mm. This corresponds to a reduction of approximately 46.9% after the central reinforced concrete core-wall system was included. The lateral displacement profiles of both models are shown in Figure 3. The results clearly indicate that the core-wall system increased the overall lateral stiffness of the building and reduced the global lateral deformation under the response spectrum loading.

The displacement profile of Model 1 shows a larger lateral deformation along the building height, which reflects the relatively flexible behavior of the moment-resisting frame system. In contrast, Model 2 exhibited a much smaller displacement profile because the central core wall provided a direct and continuous vertical lateral-force-resisting component. This behavior confirms that the addition of the core-wall system was effective in controlling the overall lateral displacement of the 10-story reinforced concrete building.

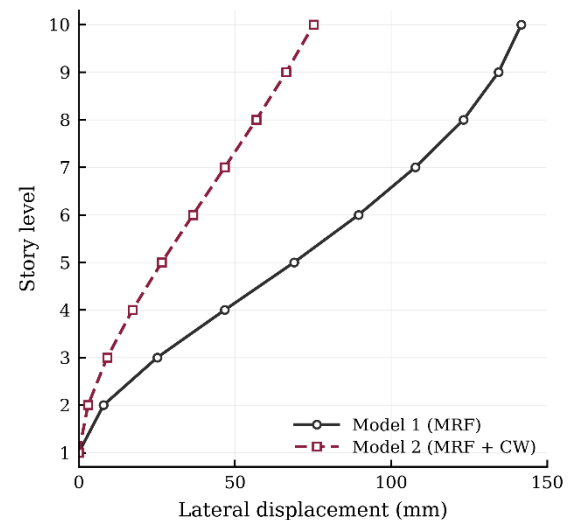


Figure 3. Lateral displacement profile of Model 1 and Model 2.

3.4 INTERSTORY DRIFT

The maximum interstory drift ratio of Model 1 was 0.007038, while that of Model 2 was 0.003369. Therefore, the maximum interstory drift ratio was reduced by approximately 52.1% when the central reinforced concrete core-wall system was included. The interstory drift distributions of the two models are shown in Figure 4. Model 1 exhibited

a larger drift response over most of the building height, with the maximum drift occurring around the middle stories. This response is typical of a relatively flexible moment-resisting frame system.

For Model 2, the interstory drift ratio was substantially reduced at all story levels. The reduction was particularly clear in the middle stories, where Model 1 showed the largest drift response. This result demonstrates that the central reinforced concrete core wall improved the drift-control performance of the building by increasing lateral stiffness and reducing story-level deformation. Since interstory drift is one of the key response parameters related to structural and nonstructural damage, the reduction observed in Model 2 indicates a significant improvement in seismic response performance compared with the frame-only system.

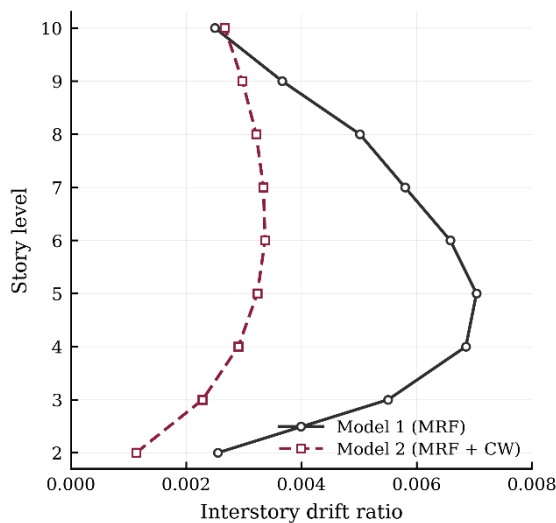


Figure 4. Interstory drift ratio of Model 1 and Model 2.

3.5 CORE-WALL SHEAR CONTRIBUTION

For Model 1, the lateral resistance was provided entirely by the moment-resisting frame system because no core wall was included. Therefore, the frame system was considered to contribute 100% of the lateral shear resistance in Model 1. For Model 2, the estimated lateral shear contribution of the central reinforced concrete core-wall system was evaluated using the pier force output at the base level.

The total scaled base shear of Model 2 was 194.589 tonf, and the core-wall shear at the base level was approximately 124.275 tonf. Based on these values, the central reinforced concrete core-wall system was estimated to resist approximately 63.9% of the total lateral shear, while the surrounding moment-resisting frame resisted the remaining 36.1%. This result indicates that the core wall carried a major portion of the lateral shear demand in Model 2.

Table 5. Estimated lateral shear contribution at the base level for Model 2.

Component	Shear force (tonf)	Contribution (%)
RC core-wall system	124.275	63.9
Moment-resisting frame	70.314	36.1
Total	194.589	100.0

4. CONCLUSIONS

This study evaluated the influence of a central reinforced concrete core-wall system on the seismic response of a 10-story reinforced concrete moment-resisting frame building in Bangkok using response spectrum

analysis. Based on the analytical results, the following conclusions can be drawn.

The addition of the central reinforced concrete core-wall system significantly increased the lateral stiffness of the building. The fundamental period decreased from 2.013 s in Model 1 to 1.328 s in Model 2, corresponding to a reduction of approximately 34.0%.

The scaled seismic base shear increased only slightly after the core-wall system was added. The base shear increased from 192.842 tonf in Model 1 to 194.589 tonf in Model 2, corresponding to an increase of approximately 0.9%. This indicates that the core-wall system substantially increased lateral stiffness without causing a significant increase in the total design base shear.

The central reinforced concrete core-wall system was effective in reducing lateral displacement. The roof displacement decreased from 141.7 mm in Model 1 to 75.2 mm in Model 2, corresponding to a reduction of approximately 46.9%.

The maximum interstory drift ratio was also substantially reduced. The maximum drift ratio decreased from 0.007038 in Model 1 to 0.003369 in Model 2, corresponding to a reduction of approximately 52.1%. This result demonstrates the effectiveness of the core-wall system in improving drift control.

Based on the pier force output at the base level, the central reinforced concrete core-wall system in Model 2 was estimated

to resist approximately 63.9% of the total lateral shear, while the surrounding moment-resisting frame resisted the remaining 36.1%. Since the shear contribution was obtained from response spectrum design output, this value should be interpreted as an estimated shear-sharing indicator rather than an exact simultaneous force distribution.

Overall, the results indicate that a central reinforced concrete core-wall system can significantly improve the seismic response of a regular mid-rise reinforced concrete building under the soft-soil conditions of Bangkok. Future studies should consider different building heights, core-wall configurations, and nonlinear time-history analysis to further evaluate the seismic performance of reinforced concrete core-wall buildings.

5. ACKNOWLEDGMENTS

The authors would like to acknowledge the Department of Civil Engineering, Faculty of Engineering, Rajamangala University of Technology Krungthep, and the Department of Civil Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, for their academic support and assistance throughout this study.

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Improving Real-Time Laboratory Equipment Detection Reliability Using Multi-Camera CCTV and ROI-Based Verification

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ABSTRACT

Manual auditing of computer-laboratory equipment is labor-intensive and prone to errors, while single-camera vision-based monitoring is often unreliable due to occlusion, viewpoint limitations, and duplicated detections. This paper proposes a real-time laboratory equipment monitoring system based on YOLOv8s, integrating multi-camera CCTV with polygon region-of-interest (ROI)-based verification to improve detection reliability. Unlike conventional multi-view approaches, the proposed system performs workstation-level verification by assigning detections to per-desk polygon ROIs and combines backup-camera verification, non-maximum suppression (NMS), and cross-camera confirmation to reduce false missing and false relocation alarms. The proposed framework was evaluated using controlled laboratory scenarios with 1,028 labeled observations. Experimental results achieved an overall classification accuracy of 90.0%, while reducing the false-missing rate from 100% using a single camera to 2.8% with the proposed multi-camera verification framework. The system operated with an average processing latency of 154 ms (6.5 FPS), demonstrating its suitability for near real-time laboratory equipment monitoring.

Keywords: equipment detection, multi-camera CCTV, region of interest, YOLO, real-time monitoring, reliability

1. INTRODUCTION

Computer laboratories in educational institutions contain large numbers of identical, portable, and valuable equipment items such as monitors, keyboards, mice, and adapters. Keeping track of these assets at scale is a well-documented problem: a 2023 audit of twenty New York school districts found that more than 20% of sampled IT assets such as laptops, tablets, and monitors could not be properly accounted for, placing nearly US\$22 million of equipment at risk of theft, loss, or misuse [1]. and a single large district reported tens

of thousands of devices lost or stolen in one school year, an 11% loss rate that its own inspector described as alarming [2].

Ensuring that every item remains at its assigned workstation is therefore important for asset management and for preventing loss or theft, a concern shared by a broad body of work on video-surveillance for abandoned-object, removed-object, and theft detection [3-8]. In current practice this verification is performed manually by staff, which is time-consuming, prone to human error, and impractical to perform continuously.

Automatic visual monitoring using object detection offers an attractive alternative, and modern detectors such as the YOLO family can locate equipment in real time [9-11]. Since its introduction, YOLO has been applied to many real-time tasks including traffic and self-driving perception [12], augmented-reality head-mounted displays [13], and video surveillance [14], and continues to be improved for small-object and multi-scale detection [15-16]. However, a single fixed camera is rarely sufficient in a realistic laboratory. Desks and monitors occlude smaller items such as mice and adapters; people working in the room temporarily block the view; and detectors occasionally report the same physical object as two overlapping boxes (a duplicated detection). Each of these effects can cause a naive counting system to raise false alarms reporting items as missing when they are merely hidden, or reporting items as relocated when they were never moved.

Conventional multi-view tracking methods primarily aim to maintain the identities and trajectories of moving targets across multiple camera views. Such systems commonly rely on appearance matching, re-identification, motion association, or Bird's-Eye-View fusion to link the same object across cameras [17-22]. In contrast, the present work addresses a static-asset verification problem in which each laboratory device is expected to remain at a predefined workstation. The proposed framework does not perform cross-camera re-identification or continuous trajectory estimation. Instead, detections are mapped to per-desk polygon ROIs, and evidence from backup cameras is selectively used to resolve desk-level inconsistencies reported by the primary-camera analysis.

The objective of this work is to improve the reliability of real-time laboratory-equipment

detection by addressing these failure modes directly. The contributions of this paper are as follows. First, we propose a verification-oriented multi-camera framework for laboratory asset monitoring, in which backup-camera observations are selectively used to verify workstation-level inconsistencies detected by the primary camera rather than for continuous cross-camera tracking. Second, we map each detection to a per-desk polygon ROI, enabling location-constrained workstation reasoning that is more precise than conventional rectangular regions. Third, we introduce a lightweight Non-Maximum Suppression (NMS) step together with a cross-camera confirmation rule to suppress duplicated detections and reduce false relocation alarms. Fourth, we develop an occlusion-aware state machine that distinguishes temporary visual occlusions from genuine equipment removal during normal laboratory operation. Finally, we validate the effectiveness of each proposed component through an ablation study using staged scenarios with known ground truth.

2. MATERIALS AND METHODS

2.1 System overview

The monitored laboratory contains fifteen workstations, labelled T01 to T15. Each workstation is expected to hold four equipment items one monitor, one keyboard, one mouse, and one power adapter giving a total of sixty items when the room is complete. Three CCTV cameras observe the room: a primary camera (C1) and two backup cameras (C2 and C3) that provide complementary viewpoints. Each camera streams video over the network, and frames are processed on a single workstation.

Processing proceeds in stages. For every processed frame the equipment detector is executed once per camera, and the resulting detections are reused by all subsequent steps to avoid redundant inference. The primary camera is analysed first; if every desk is complete and the total equals sixty, the observation is classified as NORMAL. If the primary camera reports incomplete

desks, only the existing detections associated with the corresponding desk ROIs in the backup cameras are examined for verification, without performing additional YOLO inference. The combined result is then classified, and the outcome together with its processing latency is written to a database. Figure 1 shows the overall pipeline.

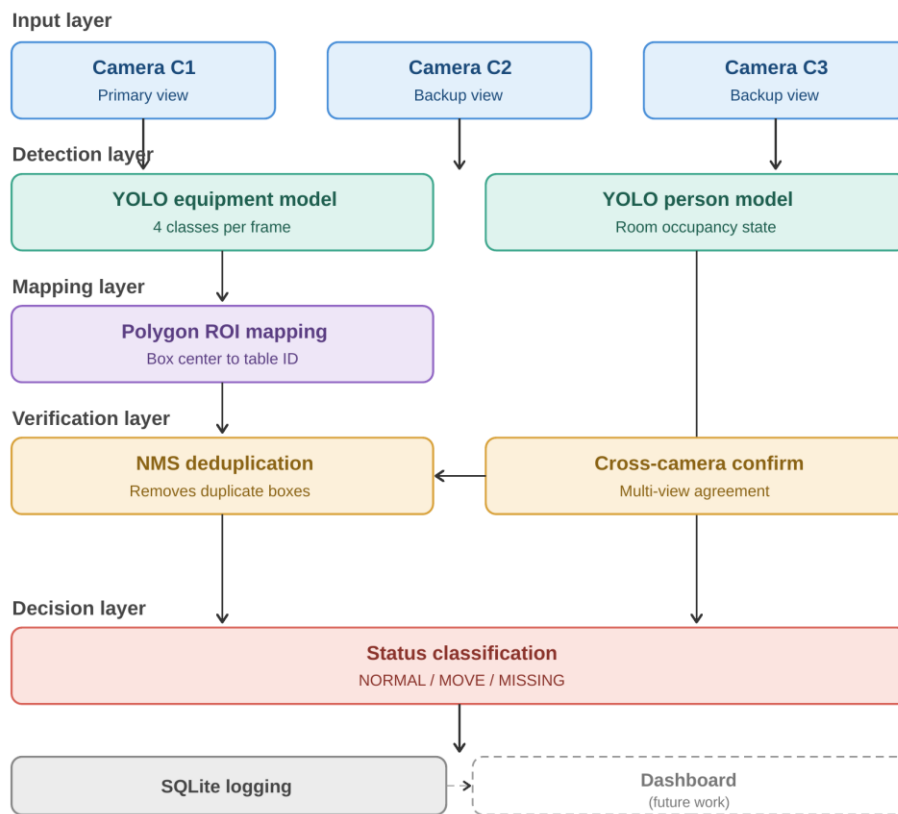


Figure 1. System architecture of the multi-camera ROI-based equipment-verification pipeline.

2.2 Dataset Preparation

A custom dataset consisting of 638 original images was collected from a computer laboratory environment using CCTV cameras installed at multiple viewpoints. The dataset contains four equipment classes: monitor, keyboard, mouse, and power adapter. The original dataset was divided into training, validation, and testing subsets. To

improve robustness under real CCTV operating conditions, data augmentation techniques including horizontal flipping, brightness adjustment, exposure variation, and blur simulation were applied to the training subset. As a result, the final dataset contained 1,721 images. All images were resized to 800 × 800 pixels prior to training.

Table 1. Original Dataset Distribution

Subset	Images	Percentage
Training	542	85%
Validation	64	10%
Testing	32	5%
Total	638	100%

Table 2. Dataset After Augmentation

Subset	Images
Training	1,625
Validation	64
Testing	32
Total	1,721

2.3 Object Detection Model and Training Configuration

Equipment detection was performed using the YOLOv8s object detection model [3,5,6]. Transfer learning was applied by initializing the network with weights pre-trained on the COCO dataset and subsequently fine-tuning the model on the laboratory equipment dataset [1]. The detector was trained to recognize four equipment classes: monitor, keyboard, mouse, and power adapter.

All images were resized to 800 × 800 pixels prior to training. The model was trained for 100 epochs with a batch size of 2 using the Ultralytics YOLO framework. Early stopping was enabled with a patience value of 20 epochs to reduce overfitting. Mosaic augmentation was gradually disabled during the final training stage by setting the close_mosaic

parameter to 10. Training was conducted on a GPU-enabled environment.

The trained YOLOv8s detector achieved 84.46% precision, 88.84% recall, 88.53% mAP50, and 42.40% mAP50-95 on the validation dataset. These results indicate that the detector was capable of recognizing laboratory equipment with satisfactory accuracy under CCTV-based monitoring conditions. However, the detection of small objects, particularly mice and adapters, remained more challenging due to their small size and long camera-to-object distance.

2.4 Equipment detection

Equipment is detected using a YOLO object detector trained to recognise the four equipment classes. A separate pretrained detector is used to count people in the room, which drives the occlusion-aware policy described in Section 2.5. Detections below a confidence threshold are discarded. To reduce computational load and provide real-time operation, detection is performed once per camera on a periodic subset of frames, and the detections are shared among all downstream counting and visualisation steps.

2.5 Polygon ROI mapping

Rather than counting equipment over the whole image, the system assigns each detection to a specific desk. A polygon ROI is defined manually for every desk in every camera view, following the visible outline of the desk surface. For each detection, the centre point of its bounding box is tested against the desk polygons; if the point falls inside a polygon, the detection is attributed to that desk, otherwise it is ignored. Polygon ROIs are used in preference to simple rectangles because adjacent desks in a wide-angle view are not axis-

aligned, and a rectangle would frequently overlap neighbouring desks and cause misattribution.

Two complementary counts are maintained per desk and class. A binary presence count records whether at least one item of a class is present, which is convenient for completeness checking. A box count records the number of distinct items after deduplication, which is required to detect surplus items at a destination desk during a suspected relocation.

(a) Primary camera (C1)



(b) backup camera (C2) (c) backup camera (C3)



Figure 2. Polygon ROI mapping used in the proposed multi-camera system: (a) primary camera (C1), (b) backup camera (C2), and (c) backup camera (C3).

2.6 Reliability mechanisms

Backup-camera re-check. When the primary camera reports a desk as incomplete, the previously computed detections associated with the corresponding desk ROIs in the backup cameras are selectively examined for verification. Because the equipment detector has already been executed once per camera, this step reuses the existing detection results without performing additional YOLO inference. Since the backup cameras observe

the room from different viewpoints, an item hidden from the primary view may still be visible, thereby reducing false missing alarms caused by occlusion and viewpoint limitations.

Non-maximum suppression (NMS). A single physical object is occasionally detected as two overlapping boxes. A lightweight NMS step merges boxes of the same class on the same desk whose intersection-over-union exceeds a threshold, so that one object is counted as one item rather than two. This prevents a duplicated detection from being misinterpreted as a surplus item.

Cross-camera confirmation. A relocation (MOVE) is declared only when a desk is missing an item and another desk shows a genuine surplus of the same class. To guard against duplicated detections that appear in a single view, the surplus must be observed by at least two cameras before a MOVE is confirmed. A real relocated object physically exists and is therefore expected to be seen by multiple cameras, whereas a duplicated detection is a single-view artefact.

Temporal smoothing. Because frame-to-frame detections fluctuate, the reported status is determined by majority vote over a short window of recent observations rather than by any single frame. This reduces flickering of the reported status.

2.7 Occlusion-aware state machine

While people are present, equipment may be temporarily hidden. To avoid raising a missing alarm for a merely occluded item, the system does not immediately report MISSING when an item is not detected. Instead, it progresses through intermediate states as the duration of non-detection increases: a short verifying state, an occluded state, and a prolonged-occlusion state. A definite MISSING status is asserted only after the room is judged empty, which is determined automatically from the people detector after no

person has been seen for a configured period. This design reflects the intuition that an item that cannot be found after everyone has left the room is more likely to be genuinely missing than one that disappears momentarily while the room is in use.

In the implemented system, an undetected item first enters the VERIFYING state for 10 s. If the item remains undetected, the status changes to OCCLUDED, and subsequently to OCCLUDED_LONG after 40 s. A SUSPICIOUS MISSING condition is triggered after 90 s of continuous non-detection. To prevent false alarms during active laboratory use, a definitive MISSING status is issued only when the room is considered empty, which occurs when no person has been detected for 60 s.

The temporal thresholds (10 s, 40 s, 90 s, and 60 s) were empirically determined through preliminary pilot experiments conducted in the target laboratory while considering typical human movement and occupancy patterns. These values were selected to balance timely detection of genuine equipment removal with robustness against false alarms caused by temporary visual occlusion.

2.8 Status definitions

Each observation is classified into one of three reported statuses. NORMAL: all desks complete and the total equals sixty. MOVE: an item is missing from one desk and confirmed as a surplus at another desk. MISSING: an item remains undetected. Internally, when an item is temporarily not detected while the room is in use, the system passes through intermediate occlusion states (a short verifying state, an occluded state, and a prolonged-occlusion state) before asserting a definite MISSING once the room is empty; these intermediate states are treated as part of the MISSING condition when results are reported. An

item relocated outside all desk ROIs — for example, placed on the floor or on an unmonitored surface as may occur when preparing to remove it — is not attributed to any desk and is therefore reported as MISSING, which is the desired behaviour.

2.9 Experimental protocol

The system was evaluated through controlled laboratory experiments using staged scenarios with predefined ground-truth conditions. For each trial, the equipment arrangement was manually configured to represent a known condition, and the corresponding ground-truth label was recorded together with the system output. The scenarios included NORMAL operation under varying lighting and occupancy conditions, relocation of equipment between desks (MOVE), removal of equipment from a desk (MISSING), and temporary occlusion caused by people or other objects. A total of 1,028 labelled observations were collected and used for performance evaluation.

To quantify the contribution of the proposed reliability mechanisms, an ablation study was conducted in which backup-camera verification, NMS-based deduplication, and cross-camera confirmation were selectively enabled and disabled. Each configuration was logged separately, allowing the effect of individual components to be analysed. System outputs were compared with the recorded ground-truth labels to compute the confusion matrix, accuracy, precision, recall, and F1-score. Processing latency was also recorded for every observation to evaluate real-time performance.

This evaluation methodology was adopted because the objective of the study was to assess the effectiveness of the complete monitoring framework, including multi-camera verification, ROI-based reasoning, occlusion-aware status transitions, and status classification, rather than the object detector alone.

3. RESULTS AND DISCUSSION

This section reports the classification performance of the full system, the ablation study quantifying the contribution of each reliability mechanism, and the real-time performance. All quantitative results were obtained from the staged experiment described in Section 2.7. In total, 1,028 labelled observations were collected for the full-system configuration. For evaluation, the occlusion-related states (verifying and occluded) are grouped with MISSING, since they all represent the system not currently confirming an item; the analysis therefore reports three categories: NORMAL, MOVE, and MISSING.

3.1 Classification performance of the full system

Table 3 reports the precision, recall, and F1-score for each status using the full system configuration, together with the overall accuracy. The system performs strongly across all three reported statuses, with F1-scores above 0.88. MOVE achieves the highest precision (0.973), indicating that relocations are reported only when well supported by cross-camera evidence, while its slightly lower recall reflects the small-item cases discussed in Section 3.4.

Table 3. Per-status classification performance of the full system.

Status	Precision	Recall	F1-score	Support
NORMAL	0.877	0.940	0.908	251
MOVE	0.973	0.805	0.881	353
MISSING	0.867	0.955	0.909	424

Status	Precision	Recall	F1-score	Support
Overall accuracy	0.900			1028

3.2 Effect of backup cameras on false missing alarms

Table 4 compares the rate of false missing alarms when only the primary camera is used against the rate when the backup cameras are enabled. Because the backup cameras observe the room from different angles, items hidden from the primary camera by occlusion or viewpoint are recovered, and the false missing rate on fully-stocked desks fell from 100% with a single camera to 2.8% with the backup cameras enabled. The mean number of detected items rose correspondingly from 47.15 to 59.16 out of sixty.

Table 4. Effect of backup cameras on detection completeness and false missing alarms

Configuration	False MISSING rate	Mean detected items
Primary camera only (C1)	100%	47.15 / 60
With backup cameras (C1+C2+C3)	2.8%	59.16 / 60

False MISSING rate measured on fully-stocked desks (ground-truth NORMAL). The backup cameras reduce the false-missing rate from 100% to 2.8%.

3.3 Robustness of the relocation logic (NMS and cross-camera confirmation)

An ablation was performed to assess the contribution of the NMS step and the cross-camera confirmation rule to the suppression of false relocation (MOVE) alarms. In contrast to the backup-camera ablation, it was found to be difficult to induce a false MOVE under controlled conditions even with these mechanisms disabled. When the NMS step was disabled, duplicated detections did appear on individual cameras, but the cross-camera confirmation rule rejected surpluses that were visible to only one camera, so the reported status fell back to a verifying (occlusion) state rather than a spurious MOVE. When items were genuinely relocated so that a surplus was visible to multiple cameras, the system correctly reported MOVE; this is a true positive rather than a false alarm.

This result indicates that the two mechanisms are complementary: with NMS disabled, cross-camera confirmation continued to filter single-view duplicates, and a false MOVE therefore did not arise. The relocation logic was consequently robust to the duplicated-detection failure mode under the tested conditions. We report this as a qualitative finding rather than a numerical false-positive rate, since the controlled scenarios did not produce false MOVE events to tabulate.

The experimental results demonstrate that the proposed reliability mechanisms substantially improve monitoring performance beyond the capability of a single-camera detector. In particular, enabling backup-camera verification reduced the false-missing rate from 100% to 2.8% on fully stocked desks, indicating that many missed detections caused by occlusion and viewpoint limitations can be recovered through the proposed verification-oriented multi-camera framework. The 100% false-missing rate observed for the single-

camera baseline should not be interpreted as complete detector failure. Rather, it reflects the workstation-level evaluation criterion adopted in this study, where a desk is considered complete only when all expected equipment items are successfully detected. Consequently, even a single missed detection, typically caused by temporary occlusion or viewpoint limitations, results in the desk being classified as incomplete. These results highlight the importance of integrating ROI-based verification, selective cross-camera confirmation, and temporal smoothing to achieve reliable laboratory equipment monitoring.

The experimental findings also reinforce the fundamental distinction between the proposed framework and conventional multi-view tracking systems. Rather than maintaining object identities or estimating trajectories across multiple camera views, the proposed framework performs workstation-level verification of static laboratory assets that are expected to remain at predefined locations. Backup-camera observations are invoked only when workstation-level inconsistencies are detected by the primary camera, eliminating the need for continuous cross-camera identity association through appearance matching, re-identification, motion association, or Bird's-Eye-View (BEV) fusion [17–22]. The substantial reduction in false-missing alarms demonstrates that this verification-oriented multi-camera framework is sufficient for reliable laboratory asset monitoring while considerably simplifying cross-camera reasoning compared with conventional multi-view tracking approaches.

3.4 Real-time performance

Table 5 reports the processing latency per detection cycle and the corresponding frame rate.

The system is intended for continuous monitoring rather than high-speed video analysis; a moderate frame rate is therefore acceptable for this application, provided that the reported latency is consistent with timely detection of equipment changes

Table 5. Real-time processing performance.

Metric	Value
Mean latency (ms)	154.1
95th-percentile latency (ms)	215
Approximate frame rate (FPS)	6.49

3.5 Discussion and limitations

The results indicate that the combination of multi-camera re-checking, NMS deduplication, and cross-camera confirmation improves the reliability of equipment detection relative to a single-camera baseline, and that the occlusion-aware policy avoids premature missing alarms while the room is in use. The ablation study isolates the contribution of each mechanism.

A clear limitation concerns the detection of relocation for small items. When a mouse is moved next to an identical item on the destination desk, the two objects are physically close and the detector frequently reports only a single box; the surplus item required to confirm a relocation therefore never appears, and the event is reported as MISSING rather than MOVE. This limitation is primarily associated with the underlying object detector and the challenges of detecting closely spaced small objects, which have also been reported in previous object-detection studies [4–6]. A related limitation is the diversity of the training data, which does not contain many examples of densely arranged identical items. Another limitation

is the relatively small image test set used for detector evaluation. Although the complete monitoring framework was validated using 1,028 staged observations, the underlying object detector was evaluated on a relatively small image test set. Future work will therefore focus on improving the detection of densely arranged small objects through additional training data, advanced multi-object detection techniques [4,12,13], evaluation on larger benchmark datasets, and k-fold cross-validation to further improve the generalizability and robustness of the detector.

4. CONCLUSIONS

This paper presented a real-time laboratory-equipment monitoring system that improves detection reliability by combining multi-camera CCTV with ROI-based verification. Detections from a YOLO detector are mapped to per-desk polygon ROIs, and three mechanisms — backup-camera re-checking, NMS deduplication, and cross-camera confirmation — are used to suppress the false missing and false relocation alarms that affect single-camera systems. An occlusion-aware state machine distinguishes temporary occlusion from genuine loss by taking room occupancy into account, reporting an occluded item as a provisional missing condition until the room is empty. The system classifies each observation as NORMAL, MOVE, or MISSING and logs the results for analysis.

In the controlled experiment the full system reached an overall classification accuracy of 90.0% over the NORMAL, MOVE, and MISSING categories. The multi-camera design was the dominant source of reliability: enabling the backup cameras reduced the false-missing rate on fully-stocked desks from 100% to 2.8%. The NMS and cross-camera confirmation mechanisms were found to act complementarily, keeping false relocations from arising even when one mechanism was

disabled. The system ran at a mean latency of 154 ms (about 6.5 frames per second), suitable for continuous near-real-time monitoring.

The principal practical implication is that combining several inexpensive reliability mechanisms on top of a standard detector yields a monitoring system that is substantially more dependable than a single-camera approach, without requiring a more powerful detector. The main limitation is the detection of relocation for closely-spaced identical small items, which the current design reports conservatively as missing. Future work will address this limitation through targeted data collection and copy-paste augmentation to improve detection of densely-arranged items, the use of object tracking to follow relocated items across desks, and the integration of radio-frequency identification (RFID) at the room exit to distinguish relocation, removal, and theft. Improvements to the streaming and inference pipeline to raise the frame rate are also planned.

5. ACKNOWLEDGMENTS

This work was supported by the Institute of Research and Development, Muban Chombueng Rajabhat University. The authors gratefully acknowledge this support, and also thank the volunteers who assisted with the staged experiment.

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Sharing bank transactions with digital payment applications the role of perceived risk in generation Y in Thailand.

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ABSTRACT

This study examines the determinants of Generation Y consumers' intention to provide bank-transaction information to digital payment application in Thailand, focusing on the intermediation effect of perceived risk. With digital financial services and open banking ecosystems growing in popularity, it is more important than ever to comprehend the psychological and behavioral factors that influence financial-data sharing. This study further modifies the TAM with the inclusion of Trust, Perceived Benefit of Integration, Perceived Control, Privacy Concern and Perceived Risk to better explain users' behavioral intention. A structured questionnaire was used to gather data from 400 respondents from Generation Y in Thailand. Confirmatory Factor Analysis (CFA) was applied to analyze the data, along with Structural Equation Modeling (SEM). The findings suggest that Perceived Benefit of Integration, Trust, and Perceived Control were significant factors in positively affecting Behavioral Intentions to share bank transaction data; and that Privacy Concern was a significant factor in negatively affecting Perceived Risk. Furthermore, Behavioral Intention was found to be influenced by Perceived Risk, and this effect was partially mediated from the effect of Privacy Concern on Behavioral Intention. The results suggest that besides having a functional convenience and usefulness, the digital payment services are also evaluated by Generation Y consumers in terms of institutional trust, security and privacy protection. The study highlights the role of perceived risk as a cognitive process in the financial data sharing decision-making process in digital payment systems. The findings are applicable to the fintech and digital-payment literature and show implications for the policy makers, fintech developers and banks to ensure sustainable use of digital financial services, improve data governance and increase consumer confidence in digital payments in Thailand.

Keywords: Digital Payment Ecosystem, Bank Transaction, Generation Y, Behavioral Intention, Perceived Risk, Thailand

1. INTRODUCTION

This study examines the factors influencing Generation Y users in Thailand when deciding to share bank transaction data with digital payment applications. The digital expansion in financial ecosystems in Thailand has increased and transformed since consumers

interact more with banking institutions and third-party fintech applications. Generation Y has impacted a critical demographic with this evolution, maintaining a generally optimistic attitude toward integrating and sharing their bank transaction data to access advanced, highly personalized financial management

features. A central problem in the current landscape is that existing technology models often how trust migrates or suffers friction when transferring from traditional banking institutions over to digital services. When Generation Y users perceive a distinct lack of control over how their sensitive transactional logs are monitored, stored, or processed, their internal privacy directly leading to strong user resistance or the outright discontinuance of these services. Perceived risk, which spans financial loss, data misuse, and system vulnerabilities, acts as a primary psychological barrier that causes individuals to completely undervalue the clear convenience and functional utility of an application. Because transactional histories reveal deeply personal lifestyle choices and individual financial stability, any perceived vulnerability in data security immediately heightens consumer reluctance and stalls ecosystem growth. However, as financial platforms transition away from traditional environments toward digital payment applications, data governance protocols frequently remain ambiguous. This structural ambiguity makes a persistent atmosphere of uncertainty, where users are forced to continuously evaluate the massive operational benefits of seamless platform integration against severe underlying privacy concerns and trust deficits expanding the Technology Acceptance Model (TAM) to incorporate trust, privacy concerns, perceived control, and the benefit of integration. Using a quantitative approach,

data was collected via a 5-point Likert scale questionnaire from 400 respondents and analyzed through Structural Equation Modeling (SEM) to evaluate both direct paths and the mediating role of perceived risk. The primary objective is to clarify how these variables interact in an environment of ambiguous data governance, providing actionable insights for financial institutions to build consumer confidence and optimize security protocols. The structural model results demonstrate that trust, perceived benefits, perceived control, and privacy concerns all exert significant direct effects on the behavioral intention to share transaction data. Furthermore, all four independent variables significantly impact perceived risk. In terms of mediation, perceived risk functions as a significant partial mediator only for the relationship between privacy concerns and behavioral intention, while the mediation paths for trust, benefit, and control were statistically unsupported. This reveals that while heightened privacy worries intensify risk perceptions and diminish user intention, Generation Y values operational control and integration as direct mechanisms of digital empowerment rather than risk-reduction tools.

2. MATERIALS AND METHODS

This research methodology is quantitative research which focus on specifically to test the relationship direct and indirect of variables with an extended Technology Acceptance Model (TAM). The

research aims to quantify how generation Y in Thailand navigates the behavior of data sharing with the banking systems. This brings the tests of hypotheses (H1–H10c), put risk as the central filter as a mediator and see how user perception data-sharing behavior. The study's target population is generation Y in Thailand with a sample size of 400 respondents that gathered through online sampling dataset. This sample size confirms to structural equation modeling to achieve adequate statistical power and stable parameter estimations. This specific generation was selected due to their high digital literacy, digital immersion and deal with concerns regarding data privacy and institutional accountability. These items were adapted from validated scales in existing literature to measure latent constructs such as benefit of integrations, trust, privacy concern, and perceived control. The questionnaire is captured using a 5-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree,". Before the final data analysis, the study conducted a thorough assessment of reliability and validity. The internal assessment was verified using Cronbach's Alpha, and confirmatory factor analysis (CFA) was used to ensure validity. The inferential statistical analysis was conducted using structural equation modeling (SEM) via Jamovi and SPSS software. This approach validated the measurement model and then tested the structural paths between variables.

3. RESULTS AND DISCUSSION

Based on the statistical analysis and structural modeling results on the findings, the hypotheses showed the critical role of perceived risk as the good filtering for financial data sharing among Generation Y in Thailand based on the conceptual framework on figure 1.

Based on the table 1. summary, and the findings on table 2-8. confirm that the primary drivers of behavioral intention which are trust (H1), benefit of integration (H2), and control (H3) maintain a significant positive influence. Especially, when generation Y users find digital payment applications valuable for managing their finances, they are willing to link their bank transactions increases confidently. Trust does not only directly boost intention but significantly reduces perceived risk (H8). For Thai users this suggests that the reputation and perceived benevolence of the financial institution serve like safety net. The study validates the privacy concern (H4) and perceived risk (H7) because the data shows that as privacy impacts the intention to share transactions declines. This relationship proves that privacy concerns work by reducing the awareness for the users. This study keeps to control (H6) because the literature often suggests that control reduces risk, the results for this indicate that generation Y values control as a direct feature digitally. Even though the mediation

path through risk was not as statistically as expected, the direct relationship to manage permissions and the intention to share data remains supported. For Thai users want to feel like active participants in the data-sharing rather than passive control bank's security.

The mediation analysis (H10a, H10b, H10c) provides the understanding of risk that the impact of trust, privacy concerns, and integration benefits on a user's final decision which determined by how these variables shift the user's risk perception. If the risk is unmanageable, the application will face rejection. In order to encourage bank transaction sharing, financial institutions and fintech developers in Thailand must move beyond the expectation. The hypotheses demonstrate that the path to adoption lies in a reduction risk strategy because of enhancement in the transparency permission controls, and leveraging institutional trust.

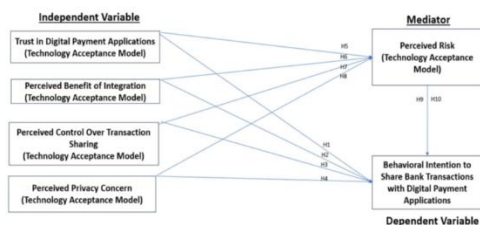


Figure 1. Conceptual Framework

Table 1. Research Hypothesis

Hypothesis ID	Relationship Type	Path / Description
H1	Direct Effect	Trust in digital payment applications has significant effect on behavioral intention to

		share bank transaction data.
H2	Direct Effect	Perceived benefit of integration has significant effect on behavioral intention to share bank transaction data.
H3	Direct Effect	Perceived control over transaction sharing has significant effect on behavioral intention to share bank transaction data.
H4	Direct Effect	Perceived privacy concern has significant effect on behavioral intention to share bank transaction data.
H5	Direct Effect	Trust in digital payment applications has significant effect on perceived risk.
H6	Direct Effect	Perceived benefit of integration has significant effect on perceived risk.
H7	Direct Effect	Perceived control over transaction sharing has significant effect on perceived risk.
H8	Direct Effect	Perceived privacy concern significant effect on perceived risk.
H9	Direct Effect	Perceived risk significant effect on behavioral intention to share bank transaction data.
H10	Mediation	Perceived risk mediates the relationship between trust and behavioral intention.
H10a	Mediation	Perceived risk mediates the relationship between perceived benefit of integration and behavioral intention.
H10b	Mediation	Perceived risk mediates the relationship

		between perceived control over transaction sharing and behavioral intention.
H10c	Mediation	Perceived risk mediates the relationship between Perceived privacy concern and behavioral intention.

Table 2 . Cronbach's α coefficient value

Item	Items	Cronbach's alpha coefficient	Interpretation
TBDA	5	0.862	Standard
PBI	5	0.849	Standard
PCT	5	0.880	Standard
PPC	5	0.870	Standard
PRMBI	5	0.882	Standard
BISBTD	5	0.876	Standard

Table 3 . Correlation Pearson Correlation

	TBDA	PBI	PCT	PPC	PRMBI	BISBTD
TBDA	1					
PBI	.381**	1				
PCT	.351**	.405**	1			
PPC	.371**	.465**	.440*	1		
PRMBI	.301**	.332**	.323*	.394*	1	
BISBTD	.327**	.426**	.382*	.362*	0.323	1

Table 4 . Fitting index of confirmatory factor analysis model

Common indicators	Judgment criteria	Value
CMIN/DF	<3	1.201
RMR	<0.05	0.05
RMSEA	<0.04	0.025
CFI	>0.9	0.984
NFI	>0.8	0.912
TLI	>0.9	0.982
PNFI	>0.8	0.818

PCFI	>0.8	0.882
p-value	<0.001	***

Table 5. Discrimination Validity (Fornell-Lacker Criterion)

	TBDA	PBI	PCT	PPC	PRMBI	BISBTD
TBD A	.787					
PBI	.345	.760				
PCT	.342	.389	.806			
PPC	.399	.460	.433	.787		
PRMBI	.301	.327	.323	.394	.803	
BISBTD	.326	.382	.358	.362	0.323	.808

Table 6 . Factor Loadings coefficients, Cronbach's Alpha, Composite Reliability Coefficient (CR), AVE, and t-value

Construct	Item	Factor Loading	Cronbach's α	(CR)	AVE
TBDA			0.862	0.89	0.62
	TBDA1	0.824			
	TBDA2	0.753			
	TBDA3	0.852			
	TBDA4	0.766			
	TBDA5	0.736			
PBI			0.849	0.87	0.58
	PBI1	0.726			
	PBI2	0.743			
	PBI3	0.851			
	PBI4	0.767			
	PBI5	0.706			
PCT			0.880	0.90	0.65
	PCT1	0.700			
	PCT2	0.823			
	PCT3	0.888			

Construct	Item	Factor Loading	Cronbach's α	(CR)	AVE
	PCT4	0.784			
	PCT5	0.823			
PPC			0.870	0.88	0.62
	PPC1	0.820			
	PPC2	0.838			
	PPC3	0.754			
	PPC4	0.795			
	PPC5	0.722			
PRMBI			0.882	0.90	0.65
	PRMBI1	0.797			
	PRMBI2	0.783			
	PRMBI3	0.860			
	PRMBI4	0.798			
	PRMBI5	0.774			
BISBTD			0.876	0.89	0.65
	BISBTD1	0.875			
	BISBTD2	0.770			
	BISBTD3	0.815			
	BISBTD4	0.774			
	BISBTD5	0.802			

Table 7 . Direct Effects of Structural Model e)

Hypot hesis	(β)	Bootst rap SE	95% Corrected CI	Result
H1	0.111	0.057	0.249	Supported
H2	0.231	0.064	0.416	Supported
H3	0.172	0.056	0.280	Supported
H4	0.156	0.058	0.260	Supported
H5	0.099	0.057	0.193	Supported
H6	0.143	0.055	0.334	Supported
H7	0.126	0.056	0.342	Supported
H8	0.217	0.058	0.242	Supported
H9	0.124	0.055	0.260	Supported

Table 8 . Direct Effects of Structural Model

Hypot hesis	(β)	Bootst rap SE	95% Corrected CI	Result
H10	0.012	0.011	(-0.004, 0.028)	Not Supported (Partial)
H10a	0.018	0.014	(-0.002, 0.038)	Not Supported (Partial)
H10b	0.016	0.012	(-0.003, 0.045)	Not Supported (Partial)
H10c	0.027	0.016	(0.004, 0.071)	Supported (Partial)

4. CONCLUSIONS

Based on the statistical analysis and structural modeling results on the findings, the hypotheses showed the critical role of perceived risk as the good filtering for financial data sharing among Generation Y in Thailand.

The findings confirm that the primary drivers of behavioral intention which are trust (H1), benefit of integration (H2), and control (H3) maintain a significant positive influence. Especially, when generation Y users find digital payment applications valuable for managing their finances, they are willing to link their bank transactions increases confidently. Trust does not only directly boost intention but significantly reduces perceived risk (H8). For Thai users this

suggests that the reputation and perceived benevolence of the financial institution serve like safety net. The study validates the privacy concern (H4) and perceived risk (H7) because the data shows that as privacy impacts the intention to share transactions declines. This relationship proves that privacy concerns work by reducing the awareness for the users. This study keeps to control (H6) because the literature often suggests that control reduces risk, the results for this indicate that generation Y values control as a direct feature digitally. Even though the mediation path through risk was not as statistically as expected, the direct relationship to manage permissions and the intention to share data remains supported. For Thai users want to feel like active participants in the data-sharing rather than passive control bank's security.

The mediation analysis (H10a, H10b, H10c) provides the understanding of risk that the impact of trust, privacy concerns, and integration benefits on a user's final decision which determined by how these variables shift the user's risk perception. If the risk is unmanageable, the application will face rejection. In order to encourage bank transaction sharing, financial institutions and fintech developers in Thailand must move beyond the expectation. The hypotheses demonstrate that the path to adoption lies in a reduction risk strategy because of enhancement in the transparency permission controls, and leveraging institutional trust.

5. ACKNOWLEDGMENTS

I really appreciate all the people who help me to complete the personal study. Without their help, the completion of the study is impossible. So, I'd like to thank all the people who supported this research as the following:

First of all, I would like to thank my parents who always support me and making my days to be possibly achieved to all my aimed targets though there are many barriers that I has to undergo.

Secondly, I really want to thank Assoc. Prof. Tanawat Teepapal, Ph.D. who provides professional guidance. As a professional guidance teacher, he is very concerned about patient to help me to finish the study of the individual, help me to better understand how to do this research.

Thirdly, I would like to thank all the surveyed attendees who participated in my personal research in Thailand through online research, without whose participation I could not have completed this research.

Last but not least, I also thank you very much for all members of the committee, Dr. Supot, Dr. Suraphong, Dr. Arti and Dr. Supaporn, they gave me a lot of attention and advice, help me to improve my study.

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An AI-Driven formative assessment framework for project-based learning in creative technology education

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ABSTRACT

Project-based learning (PBL) is fundamental to creative technology education, yet providing timely, scalable formative feedback in iterative courses like "Microcontroller and Embedded Systems" remains a significant challenge for instructors. This paper introduces FormativeAI, a novel framework designed to deliver continuous, automated formative assessment for multimedia students. Integrating static code analysis, graph-based circuit parsing, and context-aware natural language processing (NLP), FormativeAI analyzes student artifacts—including source code, schematics, and documentation to detect technical errors and conceptual gaps in electronics and programming. Instead of just giving answers, the system provides targeted, Socratic feedback and interactive mini-lessons directly within the student workflow. This empowers students to debug physical computing projects independently while liberating instructor time for higher-level creative and aesthetic mentorship. We detail the system's multi-modal engine, outline its pedagogical strategies, and illustrate its operational workflow through a representative use case, highlighting its potential to enhance learning autonomy in creative technology.

Keywords: Formative Assessment, AI in Education, Project-Based Learning, Fundamentals of Electronics and Microcontrollers

1. INTRODUCTION

A. Program context and the role of PBL

Students in the Applied Computer Science-Multimedia program in our university, there are three main learning approaches: graphic design, interactive software, and hardware. They frequently encounter difficulties learning hardware as a core subject because it involves electronics and microcontrollers areas outside their primary strengths.

In the past, PBL has significantly supported these students. In contemporary

creative technology education, particularly in disciplines such as "Microcontroller and Embedded Systems" for multimedia students, PBL serves as the cornerstone of pedagogical practice. This approach, where students engage in sustained, collaborative projects to solve real-world problems, fosters deep learning by allowing them to build tangible, interactive systems^{[1] [1]}

The inherent nature of these projects from conceptualization through design, implementation, testing, and debugging is highly iterative. They continuously refine their ideas and prototypes, learning through

cycles of experimentation and failure. For multimedia students, who often bring diverse educational backgrounds that lack formal engineering training, microcontrollers and embedded systems present a unique set of challenges. They must bridge the gap between abstract creative ideas and concrete technical execution^{Error! Reference source not found.}. Unlike traditional computer science students, their focus is often on the interactive experience and artistic expression, which necessitates a firm grasp of both software logic and fundamental electronic principles to bring their visions to life. This interdisciplinary demand makes the iterative process of physical computing particularly prone to common, recurring technical hurdles.

B. The Formative Assessment Imperative

Central to this iterative learning cycle is formative assessment, defined not merely as a grading mechanism but as a continuous process that provides feedback during learning to support and guide student progress^[3]. Unlike summative assessment, which evaluates a final product, formative assessment actively shapes the learning journey.

For multimedia students grappling with unfamiliar electronic concepts and programming paradigms, timely and precise feedback is indispensable. It helps them diagnose misconceptions, identify errors, and understand how to improve, bridging the

critical gap between their current understanding and the desired learning outcomes.

According to Sadler^[4] effective learning occurs when a student understands three crucial elements: the goal they are striving for, their current position relative to that goal and the specific actions required to close the gap between the two.

C. The feedback challenge for instructors

While the pedagogical value of formative assessment is undisputed, its effective implementation in PBL contexts especially within large or rapidly iterating classes presents significant practical challenges for instructors^[5]:

- Time Constraints: providing detailed, individualized feedback on the in-progress work of an entire class is exceptionally time-consuming. Instructors often manage dozens or hundreds of students, each with unique project paths and challenges. Manually reviewing code, circuit diagrams, and documentation for every iteration becomes logistically unsustainable, leading to superficial or delayed feedback.

- Repetitive Debugging: a disproportionately large portion of instructor time is spent diagnosing common, low-level bugs in code and circuits. These "boilerplate" issues such as missing current-limiting resistors for LEDs, improper delay() function usage, or incorrect sensor wiring detract from the more impactful creative and conceptual guidance that only a human mentor can provide. This

leads to an inefficient use of valuable instructional time.

- **Delayed Feedback:** students frequently get stuck on a problem and must wait for scheduled office hours, lab sessions, or the next class time to receive help. This delay can stall progress, lead to significant frustration, reduce motivation, and ultimately hinder the iterative learning process, especially in fields that demand rapid prototyping and continuous debugging.

D. Introducing FormativeAI

The advent of artificial intelligence technology today is both interesting and unavoidable. Therefore, utilizing its capabilities in teaching can establish a highly creative learning approach. To address these critical challenges, we propose FormativeAI, an AI-driven system engineered to function as a "digital teaching assistant."

FormativeAI is explicitly designed to operationalize Sadler's model by providing targeted insights that empower students to navigate their learning gaps independently, extending established approaches in automated programming feedback and AI-driven assessment^{[6][7]}. It aims to deliver scalable, immediate, and highly personalized formative feedback that not only corrects errors but actively reinforces foundational concepts in electro-nics and programming. By automating the identification and explanation of common technical hurdles, FormativeAI seeks to enhance student learning autonomy, accelerate the debugging

process, and liberate instructors to engage in higher-order mentorship, thereby fostering creativity and conceptual depth in their students' projects.

2. METHODOLOGY FRAMEWORK

A. System architecture overview

FormativeAI is designed as a multi-modal analysis and feedback system, leveraging the power of Artificial Intelligence to interpret and respond to the primary artifacts of creative technology projects. This architectural approach is informed by contemporary research in learning analytics and intelligent tutoring systems, which utilize student produced data to derive actionable insights and support academic performance^{[6][9][10]}. The system is envisioned as an always on resource, allowing students to submit their work-in-progress at any time for immediate, constructive feedback, thus minimizing learning bottlenecks.

The core operational flow involves three main stages: Data Ingestion & Preprocessing, Multi-Modal Analysis, and Feedback Generation as shown in Figure 1

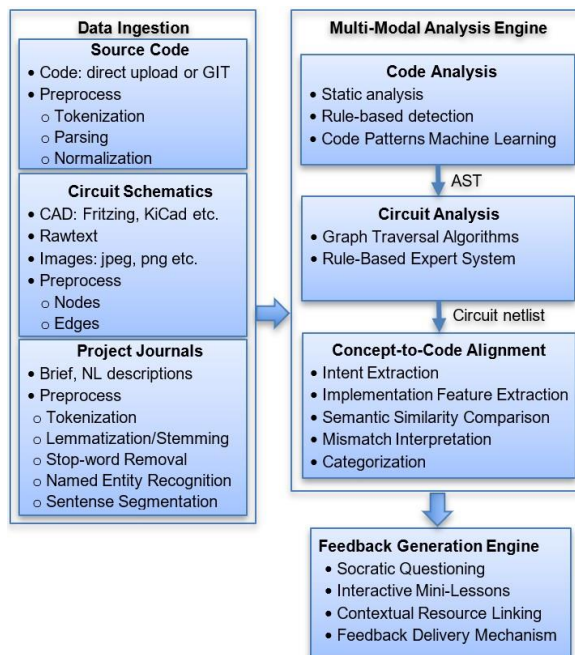


Figure 1 FormativeAI system architecture

B. Data Ingestion & Preprocessing

The effectiveness of FormativeAI hinges on its ability to accurately ingest and prepare diverse forms of student generated project data. The system is designed to accept three primary types of input, reflecting the multi-faceted nature of physical computing projects:

Source Code: it ingests C++/Arduino source files representing the microcontroller's program-matic logic either through automated Git repository integration which enables continuous assessment or via a direct upload API on the FormativeAI platform. Once ingested, the raw source code undergoes a rigorous, three-stage preprocessing pipeline to prepare it for deep analysis. First, tokenization breaks the code down into its smallest meaningful components, such as keywords, identifiers, and operators. Next, a robust parser (such as

Clang) performs parsing to construct an Abstract Syntax Tree (AST), which maps the code's hierarchical structure, control flow, and function calls. Finally, the code undergoes normalization to standardize formatting and strip out non-essential comments, ensuring analysis consistency across varying student coding styles.

Circuit Schematics: it ingests digital circuit diagrams created in structured design software, focusing primarily on formats like Fritzing (.fzz) and KiCad (.kicad_sch), which natively store data in structured XML or similar machine-readable formats. To transform this data into a canonical and analyzable format, the preprocessing engine parses these files to construct a comprehensive graph representation of the circuit. Within this network graph, individual electronic components such as microcontrollers, resistors, LEDs, and sensors are mapped as nodes containing attributes like component type, value, pin configurations, and datasheet references. The electrical pathways connecting these components are mapped as edges, which capture connection types and wire properties. This structured graph enables algorithmic traversal and automated rule validation to detect technical errors. Looking forward, the pipeline is slated to expand beyond structured files by integrating advanced computer vision and optical character recognition (OCR) techniques, allowing the engine to infer components and

connections from unstructured visual data like images of hand-drawn or exported schematics.

Project Journals: The system captures project journals in the form of brief, student-written Natural Language Descriptions (NLD) that outline project goals, design choices, progress updates, and technical challenges. These reflections are submitted either via a dedicated text field or as a Markdown file directly within the FormativeAI interface. To prepare this qualitative data for analysis, the text undergoes a standard Natural Language Processing (NLP) preprocessing pipeline. First, Sentence Segmentation and Tokenization divide the text into individual sentences and distinct words. Next, Lemmatization or Stemming reduces words to their base forms, while Stop-word Removal filters out grammatically necessary but semantically low-value words to isolate core meaning. Finally, Named Entity Recognition (NER) scans the text to identify and tag critical domain-specific entities, such as component names, software functionalities, or user interactions, enabling granular semantic analysis of the student's progress and mindset.

C. Multi-Modal Analysis Engine

This is the core intelligence of FormativeAI, consisting of specialized AI modules designed to extract meaningful insights from each input stream and identify deviations from best practices or fundamen-

tal principles. The AI components model are shown in the Figure 2.

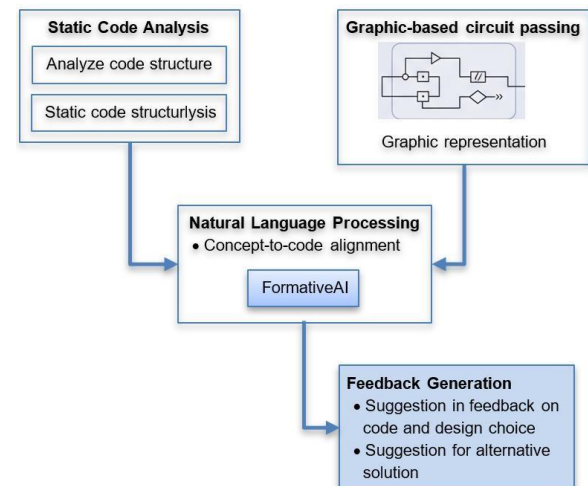


Figure 2 AI components

Code Analysis module: it moves beyond conventional linting by identifying pedagogically problematic patterns specific to embedded systems programming. Through Static Analysis & Rule-Based Detection, the module traverses the preprocessed Abstract Syntax Tree (AST) to evaluate code structure and logic without execution, leveraging techniques well-established in automated programming evaluation^{[6][10]} It checks for critical anti-patterns, including blocking functions (such as excessive delay() calls), inefficient memory allocation, improper pinMode() configurations, uninitialized variables, and missing software debouncing for inputs. For more complex structural issues, the module maps control and data flow graphs to recognize intricate design flaws. This rule-based framework is augmented by Machine Learning for Code Patterns, which utilizes a

transformer-based sequence model finetuned on a curated corpus of novice-written microcontroller code. This allows the system to detect nuanced, conceptually flawed implementations that may pass syntactic compilation but cause non-optimal performance or obscure bugs.

Circuit Analysis module: it evaluates the structural integrity of the circuit graph using a combination of graph traversal algorithms and a rule-based expert system. By executing Graph Traversal Algorithms like Breadth-First Search (BFS) and Depth-First Search (DFS), the module maps current paths, isolates connected sub-assemblies, and flags short circuits. Simultaneously, a Rule-Based Expert System evaluates the network against fundamental electronic laws and safety constraints. It applies Ohm's and Kirchhoff's laws to calculate and verify appropriate current limiting resistors for components like LEDs, flags floating digital inputs caused by missing pull-up/pull-down resistors, checks component polarity, and ensures correct pin connections for communication protocols (I2C, SPI, UART). Furthermore, the module performs rigorous power management analysis cross referencing a component database to prevent current sourcing/sinking overloads on the microcontroller rails and algorithmically recognizes functional sub-circuits, such as voltage dividers or transistor switches, to validate them against engineering best practices.

Concept-to-Code Alignment : it bridges the gap between a student's conceptual intent and their physical implementation using advanced Natural Language Processing (NLP). First, Intent Extraction applies Semantic Role Labeling (SRL), topic modeling, and keyword extraction to the student's project journal to capture their stated functional goals and design choices. Concurrently, Implementation Feature Extraction scans the source code (analyzing function names, variables, and AST logic paths) and the circuit graph (identifying physical components and hardware configurations) to map what has actually been built. Both the extracted intent and physical features are converted into high-dimensional vector embeddings using a fine-tuned Large Language Model (LLM). The module then performs a Semantic Similarity Comparison using cosine distance metrics to evaluate how closely the student's written goals align with their technical artifacts. Any significant divergence triggers Mismatch Interpretation & Categorization, identifying whether a feature is entirely missing, misimplemented (such as describing a "gradual dimming" but coding a binary digitalWrite), or indicative of a foundational conceptual disconnect regarding component behavior.

D. Feedback Generation Engine

This Engine is designed to guide and teach students rather than simply providing answers, operational-izing Sadler's model of

bridging learning gaps through timely, specific, and actionable guidance. The engine employs a hybrid architecture, combining rule-based triggers for precise error identification with fine-tuned Large Language Models (LLMs) for context-aware, natural phrasing. Rather than deliver-ing direct solutions, the system prioritizes Socratic Questioning, posing open-ended, thought-provoking prompts that encourage students to independently deduce solutions. For instance, instead of telling a student to add a missing transistor, the system prompts them to reflect on the current limitations of microcontroller pins when driving high-load devices.

When foundational engineering or programming principles are violated, the engine dynamically delivers interactive mini-lessons. These are concise, 3-to-5-minute contextual tutorials such as a quick walk-through on calculating resistance using Ohm's Law when an LED is wired directly to a power rail complete with brief embedded quizzes or simulations to immediately reinforce the correct concept. To further support self-paced correction, every piece of feedback is intelligently coupled with Contextual Resource Linking, providing immediate access to official documentation, curated electronics guides, or anonymized code examples from successful past projects. All insights are consolidated and delivered through a user-friendly Feedback Delivery Mechanism on the FormativeAI web interface, which visually

overlays feedback onto the student's code and schematics alongside real-time dashboard notifications to ensure immediate, iterative refinement.

3. SYSTEM ILLUSTRATION AND SYSTEM WORKFLOW

A. USE CASE: "Shy Lamp" project

To illustrate the theoretical workflow and intended pedagogical application of FormativeAI, consider a multimedia student, who is building an interactive "shy lamp" for his Week 5 assignment. The lamp is designed to gradually dim and physically turn away when a person approaches, utilizing a photoresistor for light detection and a servo motor for movement. He uploads his incomplete Arduino source code, a Fritzing schematic, and a brief project journal detailing his goals to the FormativeAI platform. Within moments, the system parses his multi-modal artifacts and generates the following targeted, non-punitive feedback:

Code Feedback (inefficient timing mechanism): The module flags his repeated use of `delay(20)` inside the main loop. The system generates an alert explaining that this blocking approach stalls the processor, making sensor readings less responsive and preventing simultaneous actions such as smoothly moving the servo while continuously checking light inputs. It prompts him to transition to the non-blocking `millis()` technique ("Blink Without Delay") to achieve fluid, multi-tasking interactions.

Circuit Feedback (missing voltage divider): The circuit analysis engine flags a fundamental principle omission: He connected his photoresistor directly to an analog input and ground. The feedback explains that while a photoresistor changes resistance based on light, the microcontroller's analog-to-digital converter (ADC) requires a changing *voltage* signal to register the data. FormativeAI then offers a brief, interactive mini-lesson on how a voltage divider circuit bridges this gap.

Circuit Feedback (Component Safety & Power Management): The system detects that Leo is powering his servo motor directly from the Arduino's 5V pin. It issues a high-priority warning explaining that while the microcontroller rail supplies a limited current (400–500mA), a servo motor under load can spike significantly higher. This mismatch can cause voltage "brownouts," erratic behavioral resets, or hardware damage. The engine provides an immediate technical guide on isolating high-current components using an external power supply with a shared common ground.

Through this immediate intervention, Leo resolves critical technical blockers independently without waiting for scheduled lab hours. By correcting these contextual errors, he masters a vital programming methodology (`millis()`), a core electronics principle (voltage dividers), and an essential hardware safety standard (power isolation)

directly within the workflow of his creative project.

B. Role of the Instructor & ethical considerations

Empowering the Instructor:

FormativeAI is emphatically not intended to replace the instructor. Instead, its fundamental purpose is to augment and elevate the instructor's role within the learning ecosystem. By automating the identification and delivery of feedback for common technical hurdles and foundational conceptual misunderstandings, the system strategically frees instructors from the time-consuming and often repetitive task of being a "human debugger."

This automation allows instructors to redirect their invaluable time and expertise toward what they do best: mentoring students on the higher-level creative, aesthetic, and conceptual dimensions of their work. They can engage in richer, more personalized discussions about design choices, artistic intent, user experience, and innovative problem-solving, rather than debugging circuit miswires or incorrect variable types. This shift in focus empowers instructors to be true facilitators of creativity and critical thinking, potentially leading to a more satisfying and impactful teaching experience. By automating the initial detection and explanation of standard hardware and software syntax errors, FormativeAI aims to substantially lower the time instructors spend on repetitive

debugging. This offloading is designed to maximize opportunities for high-value, individualized mentorship on project aesthetics and system design, the actual time-saving impact of which will be empirically quantified in planned pilot evaluations.

Ethical Principles in Educational AI:

the development and deployment of FormativeAI are guided by stringent ethical principles, acknowledging the sensitive nature of educational data and the profound impact of automation on student learning. To safeguard users, the system prioritizes Data Privacy & Security by rigorously anonymizing all ingested student data—using techniques like hashing student IDs and aggregating usage data—to ensure no identifiable information is linked to specific feedback instances. All data is stored securely using robust encryption and access controls in strict compliance with global data protection regulations (e.g., GDPR, FERPA), keeping students fully informed of data usage policies.

To ensure equitable treatment, the platform incorporates multi-layered Algorithmic Bias Mitigation strategies:

Diverse Datasets: the training corpus for the code analysis and NLP modules are carefully curated to encompass diverse coding styles, project types, and linguistic expressions. This prevents the system from favoring specific approaches or penalizing unconventional yet valid solutions.

Fairness Metrics & Auditing:

AI models are continuously evaluated against fairness metrics to detect disproportionate impacts on different student demographics or learning styles. Regular feedback audits are conducted by human instructors to identify and correct emergent biases.

Transparency & Explainability (XAI):

Rather than operating as a black box, FormativeAI builds trust by articulating the specific rule or model inference that triggered a given feedback item. The Socratic questioning mechanism supports this by implicitly explaining *why* an issue exists, allowing users to understand the underlying technical reasoning.

Student Agency & Autonomy:

feedback is framed strictly as pedagogical suggestions and learning opportunities rather than prescriptive commands. By avoiding a single "correct" path, the platform encourages creative exploration and independent problem-solving, fostering genuine mastery over rote compliance.

Accountability:

ultimate accountability for student outcomes remains entirely with human educators. FormativeAI functions strictly as an assistive digital teaching assistant, ensuring instructors retain full educational oversight and provide the final layer of human judgment for complex, nuanced, or highly creative challenges.

4. CONCLUSION

FormativeAI represents a timely and targeted application of Artificial Intelligence to solve a pervasive and pressing realworld problem in creative technology education: the scalability and personalization of formative feedback in project-based learning. By providing continuous, immediate, and constructively critical feedback across multiple modalities source code, circuit schematics, and reflective project documentation. The system robustly supports students through the often-frustrating debugging process, fostering independent problem-solving skills and resilience. Its innovative approach integrates direct tutoring on foundational electronics principles and programming best practices directly into the project feedback loop, actively teaching the fundamentals necessary for effective physical computing^{Error! Reference source not found.}. This multi-faceted framework not only aids in debugging but critically ensures that students build a strong conceptual foundation while engaging in their creative endeavors.

Ultimately, FormativeAI empowers instructors to transcend the role of a "human debugger" and fully embrace their potential as effective creative mentors. This paradigm shift holds the potential to significantly improve learning outcomes, enhance student satisfaction, and deepen engagement in microcontroller and embedded systems courses¹. By leveraging AI

to automate the routine, FormativeAI liberates human expertise for the truly transformative aspects of education.

A. Future Work

The FormativeAI development is envisioned as an iterative process. Key future work includes:

1) Pilot Testing and Empirical Validation: Conducting pilot studies with diverse student cohorts across different "Microcontroller and Embedded Systems" course offerings. This will involve quantitative evaluation (e.g., measuring student performance improvements, reduction in common error types, instructor time saved) and qualitative evaluation (e.g., student and instructor satisfaction surveys, feedback quality assessments).

2) Model Refinement and Expansion: Continuously refining the underlying AI models (static analysis rules, ML models for code/circuit patterns, NLP models) based on real-world usage data and expert human annotations. This includes expanding the knowledge base for a wider range of components, communication protocols, and project types.

3) Integration with Learning Management Systems (LMS): Developing seamless integration with popular LMS platforms (e.g., Canvas, Moodle) for streamlined assignment submission, grade pass-back (for summative aspects), and consolidated feedback delivery.

4) Broader Domain Applicability: Exploring the framework's adaptability to other creative technology domains, such as game development, web development, or digital fabrication.

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CGRN4FakeNews: Convolutional Gated Recurrent Network for Fake News Detection

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ABSTRACT

This study aims to (1) examine the effectiveness of the Convolutional Gated Recurrent Network for Fake News Detection (CGRN4FakeNews) model in fake news classification and (2) compare its performance with baseline methods across different datasets. The model was evaluated using the PolitiFact and GossipCop subsets of the FakeNewsNet dataset. The research process involved text preprocessing and data cleaning, including word tokenization, lowercasing, the removal of URLs, HTML tags, numerical values, punctuation marks, and redundant whitespace, as well as stopword handling. The processed text data were then transformed into vector representations using a word embedding technique for model training and evaluation. The model performance was assessed based on Accuracy, Precision, Recall, F1-score, and Confusion Matrix metrics. The experimental results indicate that the proposed CGRN4FakeNews model effectively distinguishes between real and fake news articles, achieving classification accuracies of 95.75% on the PolitiFact dataset and 91.12% on the GossipCop dataset. These findings demonstrate the effectiveness and suitability of the CGRN4FakeNews model for fake news detection tasks.

Keywords: Fake News, deep Learning, text classification

1. INTRODUCTION

The rapid growth of social media and online news platforms has significantly changed the way information is disseminated in the digital era. However, the widespread distribution of fake news has become a critical issue, influencing public trust and decision-making processes. Fake news is defined as false or misleading information presented in the form of credible news content with the intention of deceiving readers or shaping public opinion [1]. In addition, misinformation spreads much faster than factual information, making manual fact-checking increasingly challenging [2]. As a result, artificial intelligence techniques have been extensively applied for

automated fake news detection, particularly in text classification tasks [3].

Traditional machine learning methods, such as Decision Tree and Random Forest, are widely used because of their simplicity and computational efficiency [4][5]. However, these methods have limitations in capturing sequential dependencies within textual data. In contrast, neural network models are more capable of learning hierarchical and contextual representations. Among these models, Convolutional Neural Networks (CNN) are effective for extracting local textual features [6], whereas Recurrent Neural Networks (RNN), particularly Gated Recurrent Units (GRU), are well suited for modeling sequential dependencies [8].

Therefore, this study employs a hybrid CGRN4FakeNews model for fake news detection using the PolitiFact and GossipCop subsets of the FakeNewsNet dataset [12]. The model integrates CNN for textual feature extraction and GRU for learning sequential dependencies. The model is evaluated using Accuracy, Precision, Recall, F1-score, and Confusion Matrix metrics. The experimental results indicate that the proposed model achieves high classification performance and outperforms baseline models.

2. MATERIALS AND METHODS

The methodology of the study entitled “CGRN4FakeNews: Convolutional Gated Recurrent

Network for Fake News Detection” is presented in the following sections.

A. Data Preprocessing

In this study, the FakeNewsNet dataset introduced by Kai Shu et al. (2020) [12] was employed as a benchmark dataset widely used in fake news detection research. The experiments were carried out using the PolitiFact and GossipCop subsets. The PolitiFact dataset contains 1,056 news articles, consisting of 624 real news articles and 432 fake news articles. In comparison, the GossipCop dataset includes 22,140 news articles, with 16,817 real news articles and 5,323 fake news articles. For the experimental process, only the news titles were used as input data for analysis. The class labels were assigned as 0 for real news and 1 for fake news.

Table 1. Presents sample records from the FakeNewsNet dataset and its main data attributes.

Dataset	id	news_url	title	Tweet_ids
PolitiFact	PolitiFact15354	https://exclusive103.com/2018/04/30/thousands-killed-as-israel-drops-tactical-nuclear-bomb-on-syria/	Thousands killed as Israel Drops Tactical Nuclear Bomb On Syria	990880029549694976 992661084896219136
GossipCop	gossipcop-6068765070	radaronline.com/exclusives/2018/07/ben-affleck-best-friend-matt-damon-life-coach-advice/	He is Hired! Ben Affleck Enlists Best Friend Matt Damon To Be His Life Coach	911376015317970000

Table 2. Selected news titles and labels from the FakeNewsNet dataset used for the experiment.

Dataset	Title	Label
PolitiFact	Palin tries new tactic to unload hated jet: Gov. Sarah Palin background	Real
	Australia Becomes First Country To Begin Microchipping Its Citizens	Fake
GossipCop	Kenya Moore gives birth to first child	Real
	Liam Payne Talks Possibility Of Starting An Acting Career	Fake

Data preprocessing is an essential step for both the CGRN4FakeNews model and the baseline models. The process begins with text cleaning, which includes converting all text to lowercase, removing URLs, HTML tags, numerical values, punctuation marks, and stop words, as well as eliminating redundant whitespace. These steps ensure that the news headlines are standardized and prepared for further processing.

The cleaned text is then transformed into a machine-readable format through tokenization, in which words are converted into sequences of numerical indices. The maximum vocabulary size was set to 5,000 words for the PolitiFact dataset and 10,000 words for the GossipCop dataset. All sequences were padded to a fixed length of 20 tokens, which was considered appropriate for news headline texts.

Finally, the dataset was split into 70% training, 10% validation, and 20% testing sets. The training set was used for model training and parameter optimization, whereas the testing set was utilized for performance evaluation.

B. Model Development

After preprocessing, an Embedding layer is first employed to convert words into dense vector representations, followed by a SpatialDropout1D layer to reduce overfitting. The embedded features are then processed through Conv1D and MaxPooling1D layers to extract important textual features. Next, the extracted features are passed into a GRU layer with 32 units to capture sequential dependencies and contextual information within the text. The GRU utilizes update and reset gates to regulate the flow of information, enabling the model to retain relevant contextual features while alleviating the vanishing gradient problem. Finally, a Dense layer with a sigmoid activation function is applied for binary classification of real and fake news, optimized using the Binary Crossentropy loss function. To improve generalization, a dropout rate

of 0.5 and Early Stopping are applied during training. In addition, the Class Weight technique is applied to the GossipCop dataset to address class imbalance. Since the ratio of the majority class (Class 0) to the minority class (Class 1) is approximately 3:1, class weights of 1.0 and 3.0 are manually assigned to Class 0 and Class 1, respectively, to increase the contribution of minority-class samples during training.

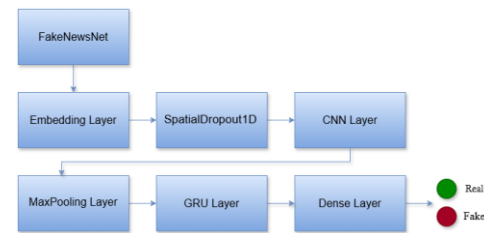


Figure 1. CGRN4FakeNews Architecture

C. Model Evaluation

To evaluate the performance of the proposed model, standard classification metrics were employed, including Accuracy, Precision, Recall, F1-score, and Confusion Matrix. These metrics were used to assess the effectiveness of the model in distinguishing between real and fake news.

Accuracy measures the overall proportion of correctly classified instances out of the total number of instances. Precision evaluates the proportion of correctly predicted fake news instances among all instances classified as fake news, whereas Recall measures the proportion of actual fake news instances correctly identified by the model. The F1-score provides a balanced measure of Precision and Recall, reflecting the overall classification performance of the model.

In addition, the Confusion Matrix was used to visualize the classification results and analyze the number of correct and incorrect predictions for each class.

3. RESULTS AND DISCUSSION

To evaluate the performance of the proposed fake news detection model, it was compared with several machine learning and deep learning models, including Decision Tree, Random Forest, XGBoost, LSTM, GRU, and CGRN4FakeNews. The models were assessed using Accuracy, Precision, Recall, and F1-score on the PolitiFact and GossipCop datasets. The experimental results indicate that the proposed CGRN4FakeNews model outperformed the baseline models across all evaluation metrics on both datasets. The detailed results are presented in the corresponding tables.

A. PolitiFact Dataset

Table 3. The experimental results of the PolitiFact dataset

Model	Acc.	Prec.	Rec.	F1
Decision Tree	0.7123	0.6484	0.6705	0.6592
XGBoost	0.7736	0.7222	0.7386	0.7303
Random Forest	0.7783	0.7356	0.7273	0.7314
LSTM	0.9340	0.9512	0.8864	0.9176
GRU	0.9434	0.9524	0.9091	0.9302
CGRN4FakeNews	0.9575	0.9540	0.9432	0.9486

Table 3 presents a performance comparison of machine learning and deep learning models on the PolitiFact dataset. The results indicate that the proposed CGRN4FakeNews model outperformed all baseline models across all evaluation metrics, achieving the highest Accuracy of 0.9575 and F1-score of 0.9486. Among the baseline models, GRU demonstrated the second-best performance, followed by LSTM, whereas the machine learning models exhibited lower classification performance. These findings confirm the effectiveness of the proposed model for fake news detection.

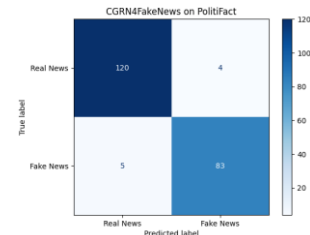


Figure 2. Confusion Matrix of CGRN4FakeNews on PolitiFact. Figure 2 presents the confusion matrix of the CGRN4FakeNews model on the PolitiFact dataset. The model correctly classified 120 real news articles and 83 fake news articles, while only 4 real news articles were incorrectly classified as fake news and 5 fake news articles were incorrectly classified as real news. These results indicate that the proposed model achieved high classification accuracy with a relatively low number of misclassifications.

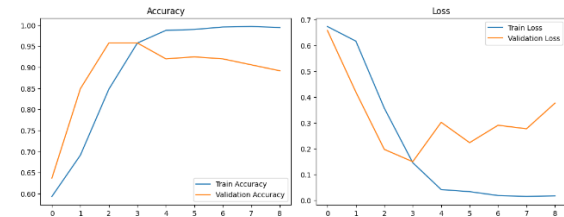


Figure 3. Accuracy and Loss Curves of CGRN4FakeNews (PolitiFact)

Figure 3 illustrates the accuracy and loss curves of the CGRN4FakeNews model during the training process. The results show that both training and validation accuracy increased steadily, while the training and validation loss decreased significantly during the early epochs. However, the validation loss exhibited a slight increase in the later epochs, indicating mild overfitting. Overall, the model demonstrated effective learning performance and satisfactory convergence.

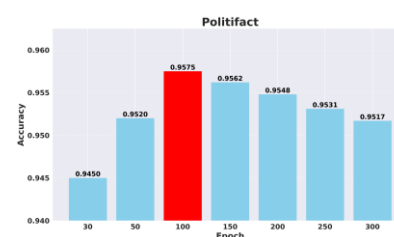


Figure 4. Effect of Training Epochs on CGRN4FakeNews Accuracy (PolitiFact)

Figure 4 presents the effect of different training epochs on the performance of the CGRN4FakeNews model. The results indicate that the highest accuracy of 0.9575 was achieved at 100 epochs. After that, the accuracy slightly decreased, suggesting that excessive training may lead to overfitting.

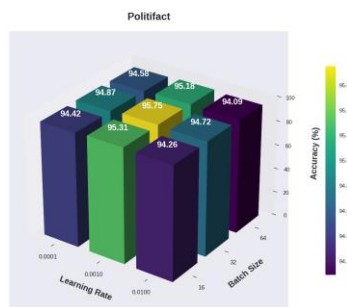


Figure 5. Effect of Learning Rate and Batch Size on CGRN4FakeNews Performance (PolitiFact)

Figure 5 illustrates the effect of learning rate and batch size on the performance of the CGRN4FakeNews model. The highest accuracy of 95.75% was achieved with a learning rate of 0.001 and a batch size of 32. These results indicate that appropriate hyperparameter settings are important for achieving optimal performance.

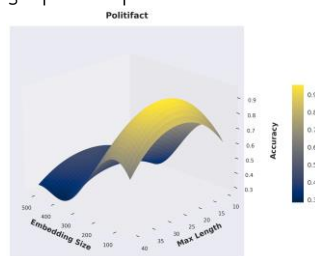


Figure 6. Impact of Embedding Size and Sequence Length on CGRN4FakeNews Performance (PolitiFact)

Figure 6 presents the effect of embedding size and maximum sequence length on the performance of the CGRN4FakeNews model. The results indicate that the highest accuracy was achieved when the embedding size ranged from 100 to 150 and the maximum sequence length ranged from 20 to 30.

However, larger embedding sizes resulted in lower performance.

B. GossipCop dataset

Table 4. The experimental results of the GossipCop dataset

Model	Acc.	Prec.	Rec.	F1
Decision Tree	0.7342	0.4638	0.5429	0.5002
XGBoost	0.7843	0.5825	0.4320	0.4901
Random Forest	0.7873	0.6252	0.3290	0.4312
LSTM	0.8930	0.7596	0.8240	0.7905
GRU	0.9063	0.8002	0.8230	0.8114
CGRN4FakeNews	0.9112	0.8051	0.8415	0.8229

Table 4 presents a performance comparison of machine learning and deep learning models on the GossipCop dataset. The results indicate that the proposed CGRN4FakeNews model outperformed all baseline models across all evaluation metrics, achieving the highest Accuracy of 0.9112 and F1-score of 0.8229. These findings confirm the effectiveness of the proposed model in maintaining a balance between Precision and Recall for fake news classification. Among the baseline models, GRU demonstrated the second-best performance, followed by LSTM, whereas the machine learning models exhibited lower classification performance.

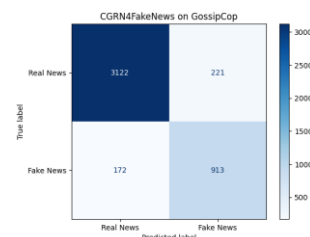


Figure 7. Confusion Matrix of CGRN4FakeNews on GossipCop

Figure 7 presents the confusion matrix of the CGRN4FakeNews model on the GossipCop dataset. The model correctly classified 3,122 real news articles and 913 fake news articles, while 221 real news articles were misclassified as fake and 172 fake news articles were misclassified as real. The results indicate a tendency toward predicting real

news, which may be attributed to class imbalance in the GossipCop dataset, where real news articles outnumber fake news articles. Nevertheless, the model still achieved relatively strong classification performance, as the number of correctly classified instances was substantially higher than the number of misclassified instances.

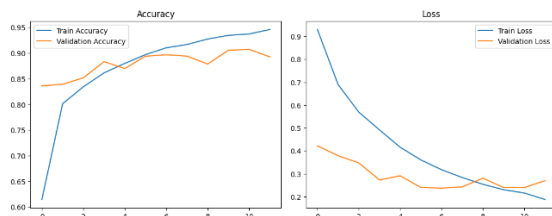


Figure 8. Accuracy and Loss Curves of CGRN4FakeNews (GossipCop)

Figure 8 illustrates the accuracy and loss curves of the CGRN4FakeNews model during training on the GossipCop dataset. The results show that both training and validation accuracy increased steadily, while both training and validation loss decreased in the early epochs, indicating effective learning. However, the validation loss exhibited a slight increase in the later epochs, suggesting moderate overfitting. Overall, the model demonstrated satisfactory convergence during the training process.

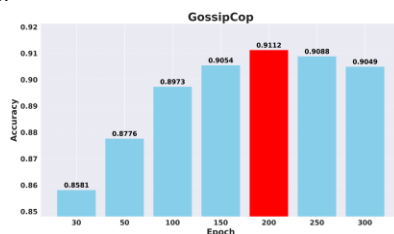


Figure 9. Effect of Training Epochs on CGRN4FakeNews Accuracy (GossipCop)

Figure 9 presents the effect of different training epochs on the CGRN4FakeNews model using the GossipCop dataset. The results show that model accuracy gradually increased as the number of epochs increased, reaching a maximum accuracy of 0.9112 at 200 epochs. After that, the accuracy slightly decreased, indicating that excessive training may lead to overfitting.

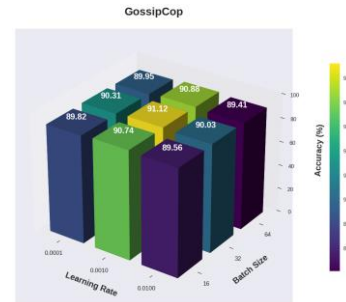


Figure 10. Effect of Learning Rate and Batch Size on CGRN4FakeNews Performance (GossipCop)

Figure 10 illustrates the effect of learning rate and batch size on the CGRN4FakeNews model using the GossipCop dataset. The highest accuracy of 91.12% was achieved with a learning rate of 0.001 and a batch size of 32. These results indicate that appropriate hyperparameter settings contribute to improved model performance.

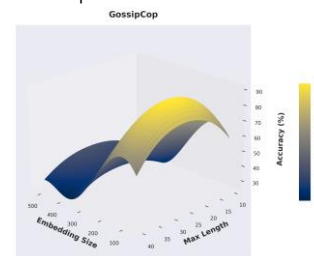


Figure 11. Impact of Embedding Size and Sequence Length on CGRN4FakeNews Performance (GossipCop)

Figure 11 presents the effect of embedding size and maximum sequence length on the CGRN4FakeNews model using the GossipCop dataset. The results indicate that the highest accuracy was achieved when the embedding size ranged from 100 to 150 and the maximum sequence length ranged from 20 to 30. However, larger embedding sizes resulted in lower classification performance.

4. CONCLUSIONS

The experimental results demonstrate that the proposed CGRN4FakeNews model outperformed traditional machine learning and baseline deep learning models on both the PolitiFact and GossipCop datasets, achieving the

highest Accuracy and F1-score. These findings confirm that the integration of CNN for feature extraction and GRU for sequential dependency learning effectively improves fake news classification performance.

However, slight overfitting was observed in the later stages of training, and model performance was affected by class imbalance in the GossipCop dataset. In addition, this study was limited to using only news headlines for analysis, which may not fully capture the complete context of the news.

The findings highlight the practical potential of hybrid deep learning models for automated fake news detection and content screening systems. For future work, multimodal data sources and advanced architectures, such as Transformer-based models and BERT, are recommended to further improve classification performance and generalization capability.

5. ACKNOWLEDGMENTS

The authors thank Major of Information Technology and Digital Business, Faculty of Business Administration, Rajamangala University of Technology Krungthep, Bangkok, Thailand for their supports.

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Effect of water depth on benthic macroinvertebrate taxonomic group diversity in a freshwater stream of Khao Yai National Park, Thailand

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ABSTRACT

This study investigated the effect of water depth on benthic macroinvertebrate taxonomic group diversity in a freshwater stream in Khao Yai National Park, Thailand. Water depth was the independent variable and was measured at 50 sampling points distributed across five transects. Macroinvertebrates were collected using a standardized kick sampling method and taxonomic group diversity was quantified using the Shannon–Wiener index (H').

The results showed a weak positive correlation between water depth and biodiversity ($r = 0.3056$). This relationship was not statistically significant ($p \approx 0.46$, $p > 0.05$) and suggests that water depth alone was not a major determinant of diversity, while other confounding factors such as substrate composition and flow velocity appeared to influence biodiversity patterns.

These findings suggest that benthic macroinvertebrate diversity is influenced by multiple interacting environmental factors rather than water depth alone and support the importance of considering habitat characteristics such as substrate and flow conditions. Future studies should increase replication and sample a wider depth range, and additional abiotic variables should be measured directly to better understand biodiversity patterns.

Keywords: benthic macroinvertebrate, biodiversity, water depth, Shannon–Wiener index, freshwater stream, Khao Yai National Park

1. INTRODUCTION

Freshwater ecosystems are biologically diverse and contribute greatly to maintaining ecological stability (4). Streams are changing environments that can vary both spatially and temporally due to abiotic factors such as water velocity, substrate composition, dissolved oxygen and water depth which affect organism distribution (1).

This investigation was carried out at a stream in Khao Yai National Park which is a UNESCO

World Heritage Site with low anthropogenic disturbance and high biodiversity, in the hope of clearer links between biological patterns and abiotic variation.

Benthic macroinvertebrates are animals, visible to the naked eye that inhabit freshwater stream beds (6). These organisms include annelids and crustaceans but are mostly aquatic insects. Benthic macroinvertebrates contribute to nutrient cycling, decomposition of organic matter and (3) are commonly used as bioindicators due to their limited mobility and varying environmental tolerance, where shifts in their population structure indicate environmental variation (2).

In this study, macroinvertebrates were classified into taxonomic groups, including, aquatic insect larvae, aquatic insect nymphs, adult aquatic insects, aquatic worms, and crustaceans and mollusks. This

method allows standardized biodiversity measurement since species level identification was not practical under field conditions and would reduce reliability. The

Shannon–Wiener index was used to quantify diversity since it accounts for both taxonomic richness and evenness (5).

Water depth was chosen as the independent variable since it influences key abiotic factors such as light penetration, dissolved oxygen and substrate stability (1). Changing water depths are often linked with riffle–pool sequences, creating contrasting habitats that influence organism distribution (7). Shallow, fast-moving sections have higher light penetration, more turbulence and aeration, leading to higher dissolved oxygen. These conditions favor taxonomic groups adapted to fast flow conditions and high oxygen availability, while deeper, slower flowing areas favor organisms adapted to lower light and reduced flow environments.

According to the ecological niche theory, abiotic factors such as water depth help determine the environmental conditions under which organisms can survive and reproduce, influencing the distribution of freshwater communities (9).

Therefore, this study investigated how water depth influences benthic macroinvertebrate taxonomic group diversity along a freshwater stream in Khao Yai National Park, Thailand. Macroinvertebrates were collected using systematic kick sampling along a 25 m stream section and diversity was quantified using the Shannon–Wiener index (H').

2. MATERIALS AND METHODS

2.1 Variables

Water depth was the independent variable and was measured as the vertical distance from the stream bed to the water surface (cm) at predetermined

sampling points along transects using the same meter ruler to maintain consistency. Depth values were grouped into 4 cm intervals to increase sample size and reliability.

The dependent variable was benthic macroinvertebrate taxonomic group diversity, quantified using the Shannon–Wiener biodiversity index (H'). At each site, macroinvertebrates were collected and classified into taxonomic groups using the Freshwater Name Trail pictorial dichotomous key (Appendix A). The Shannon–Wiener index was used as it accounts for both richness and evenness.

To ensure reliability, the sampling method, sampling duration, transect placement, time of sampling, identification method and number of sampling points were standardized throughout the investigation. Standardized kick sampling was conducted at all sampling points, substrate disturbance was maintained at 30 seconds, transects were placed perpendicular to the stream bank at 5 m intervals and all sampling was conducted during a single field session. Additionally, the same identification key was used throughout, and ten equally spaced sampling points were established at each transect.

2.2 Ethical considerations

All organisms were handled carefully and identified as quickly as possible to minimize stress and disturbance. After identification, all organisms were immediately returned to their original sampling locations. Permission was acquired by the school from relevant authorities to conduct research within the protected area.

2.3 Sampling method

Systematic sampling was used to reduce selection bias and ensure data were collected evenly across the whole stream. The total length of the site was

measured and divided into five equal sections, with transects placed at 5 m intervals to ensure even coverage and capture the variation in water depth. Each transect was placed perpendicular to the stream bank. At each transect, the width of the stream was measured and divided into ten equal intervals to determine the sampling points making sure the data was a reliable representation of variation in water depth across the stream.

2.4 Preliminary investigation

A preliminary investigation was conducted the day before to determine an appropriate time for substrate disturbance. A duration of 30 seconds was decided as this time provided a sufficient number of benthic macroinvertebrates from kick sampling while limiting habitat disturbance.

2.5 Method

A 25 m section of the stream was selected and measured using a 30 m measuring tape (± 0.01 m). This section was divided into five equal intervals, with a transect placed at the midpoint of each interval. Each transect was perpendicular to the stream bank and sampling began at the most downstream transect. The stream width was measured using a 30 m measuring tape (± 0.01 m) at each transect. Transect length was standardized to half of the measured stream width. This length was

then divided into ten equal intervals to determine sampling points. At each sampling point, water depth (cm) was measured using a meter ruler (± 0.1 cm). A kick net (1 mm mesh size) was placed downstream of the sampling point. A 1 mm mesh size was selected to make sure benthic macroinvertebrate size was large enough for reliable identification while minimizing the collection of fine sediment and sand. The substrate upstream was disturbed using kick sampling for 30 seconds timed by a stopwatch (± 0.01 s). Organisms collected were transferred to a white sorting tray and identified using a pictorial dichotomous key, “The Freshwater Name Trail” (see Appendix A), using a 10x magnifying glass when required. Organisms were classified into predefined taxonomic groups, and the procedure was repeated at all ten sampling points for the five transects. Sampling points were spaced out, and sampling was conducted downstream of the net to reduce recapture and maintain independence.

2.6 Study site characteristics

The physical characteristics of the site were recorded to provide context across transects. Additional qualitative observations were made at each transect to describe substrate composition and flow rate, as these factors may act as confounding variables influencing the relationship between depth and diversity.

Table 2.1 – Physical characteristics of sampling site

Transect	Stream width (m ± 0.01)	Depth range (cm ± 0.1)	Substrate type	Flow rate	Additional observations
1	10.6	6.0 – 42.0	Fine sediment	Moderate (downstream of a riffle)	-
2	10.0	5.5 – 18.5	Large boulders (riffle zone)	High (riffle zone)	-

3	9.4	3.0 – 11.5	Rocks with algal growth	Medium	Presence of mid-channel bar with leaf-litter dominated substrate
4	8.0	8.0 – 29.0	Medium sized rocks with some sand	Low	-
5	8.0	11.0 – 37.2	Sand and silt	Low	-



Figure 2.1 – Mid-channel bar at Transect 3 with leaf-litter-dominated substrate and minimal flow, limiting data collection at several sampling points.

3. RESULTS AND DISCUSSION

3.1 Biodiversity patterns across depth ranges

A total of six benthic macroinvertebrate taxonomic groups were recorded across the five transects. The macroinvertebrate community was dominated by aquatic insect nymphs, which were the most abundant group throughout the study. Aquatic worms and aquatic insect larvae were also commonly observed across the transects, whereas adult aquatic insects and freshwater crustaceans and mollusks occurred at comparatively lower abundances. Other aquatic macroinvertebrates were unevenly distributed, with higher abundances recorded in some transects, particularly Transect 2 and Transect 4. The dominance of aquatic insect nymphs, together with the widespread occurrence of aquatic insect larvae, suggests that much of the study site provided favorable habitat conditions capable of supporting diverse freshwater macroinvertebrate communities.

Mean H' values were calculated for each depth range to allow comparisons across the depth gradient.

Table 3.1 – Mean Shannon–Wiener diversity index (H') across water depth ranges.

Depth range (cm)	Midpoint (cm)	Mean H'	n
3.0 – 6.9	4.95	0.868	3
7.0 – 10.9	8.95	1.139	2
11.0 – 14.9	12.95	1.101	5
15.0 – 18.9	16.95	0.851	2
19.0 – 22.9	20.95	0.930	2
23.0 – 26.9	24.95	1.080	2
27.0 – 30.9	28.95	1.211	2
31.0 – 34.9	32.95	1.011	2
35.0 – 38.9	36.95	1.011	1
39.0 – 42.9	40.95	1.392	1

The highest mean diversity value was observed at the 39.0–42.9 cm depth range ($H' = 1.392$) while the lowest was observed at the 15.0–18.9 cm depth range ($H' = 0.851$). Diversity values varied across depth categories without showing a consistent increasing or decreasing pattern.

The relationship between water depth and benthic macroinvertebrate taxonomic group diversity is illustrated in Figure 3.1 Categories with $n \leq 2$ were excluded from correlation analysis because the small number of replicates made mean diversity values less reliable and more susceptible to random variation.

Relationship between water depth and benthic macroinvertebrate diversity

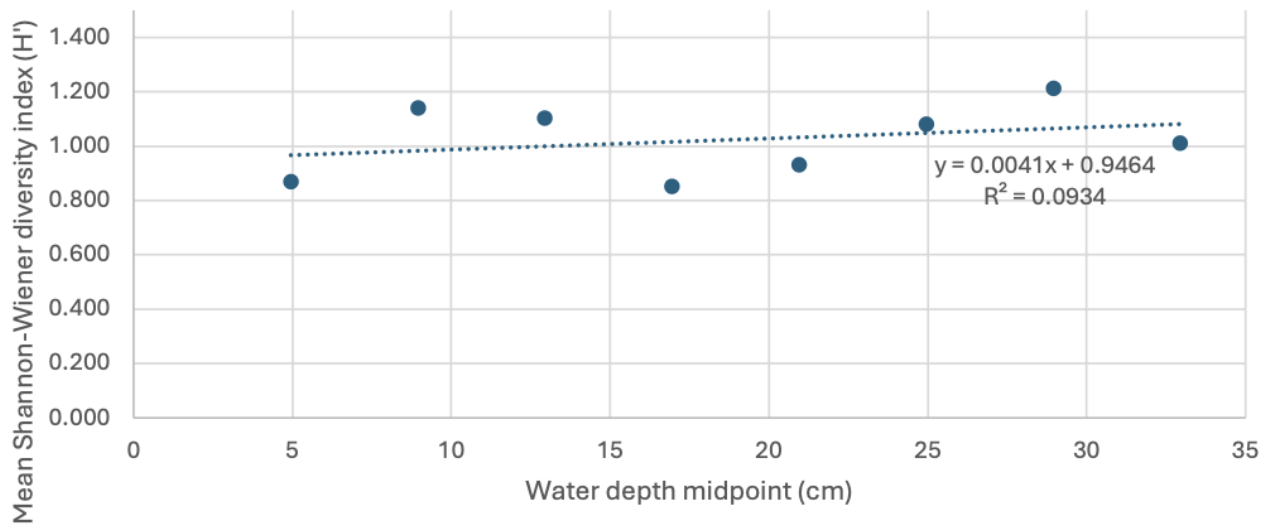


Figure 3.1 – Scatter graph showing the relationship between water depth (cm) and benthic macroinvertebrate diversity (H').

Pielou's Evenness Index (J') was calculated for each depth range to compare the evenness of benthic macroinvertebrate taxonomic groups across the depth gradient.

Table 3.2 – Mean Shannon–Wiener diversity index (H') and Pielou's Evenness Index (J') across water depth ranges

Depth range (cm)	Mean H'	Pielou's Evenness Index (J')	Taxonomic richness (S)
3.0 – 6.9	0.868	0.563	5
7.0 – 10.9	1.139	0.708	5
11.0 – 14.9	1.101	0.615	6
15.0 – 18.9	0.851	0.775	3
19.0 – 22.9	0.930	0.578	5
23.0 – 26.9	1.080	0.671	5
27.0 – 30.9	1.211	0.752	5
31.0 – 34.9	1.011	0.730	4
35.0 – 38.9	1.011	0.921	3
39.0 – 42.9	1.392	0.865	5

The highest evenness value was observed at the 35.0–38.9 cm depth range ($J' = 0.921$), while the lowest was observed at the 3.0–6.9 cm depth range ($J' = 0.563$). Evenness values varied across depth categories without showing a consistent increasing or decreasing pattern.

3.2 Summary of findings

Figure 3.1 showed a weak positive correlation between water depth and benthic macroinvertebrate taxonomic group diversity ($r = 0.3056$). As water depth increased, the Shannon–Wiener diversity index (H') shows a slight increase. However, the small gradient (0.0041) and low R^2 value (0.0934), suggest that water depth explained only a small proportion of variation in diversity. Therefore, water depth was not a strong factor affecting biodiversity at the sampling site, so the null hypothesis could not be rejected. This trend was opposite to the negative correlation predicted, therefore this directional hypothesis was not supported by the data. As shown in Figure 3.1, mean diversity values varied across depth categories and did not display a clear decreasing trend. The student's t-test further showed that the relationship is not statistically significant ($p \approx 0.46 > 0.05$), indicating that other abiotic factors may have influenced biodiversity patterns.

3.3 Ecological interpretation

Although the hypothesis predicted a negative correlation between water depth and biodiversity due to abiotic factors such as light penetration and dissolved oxygen concentration, the results suggest that depth alone does not significantly influence benthic macroinvertebrate taxonomic group diversity. For example, the highest mean diversity ($H' = 1.211$ at 28.95 cm) was not seen at the shallowest depth (4.95 cm), indicating that depth interacts with other environmental variables such as flow velocity and substrate composition. These combined factors influence the overall composition

and diversity of benthic macroinvertebrates and are more biologically significant particularly in the context of Odum's ecological principles and the concept of n-dimensional hyper niche space. This also aligns with past research carried out by the River Continuum Concept, which suggests that stream communities are structured by changes in environmental conditions and energy inputs along the longitudinal profile rather than depth alone (7).

For example, transect 2 was in a riffle zone and showed high biodiversity despite low depth values. This area was dominated by large boulders and characterized by high flow velocity, creating microhabitats that provide shelter from predation and fast flow. This increases niche availability which supports higher macroinvertebrate diversity. Aquatic worms were also frequently observed near riffles (Figure 2.1), suggesting that certain groups benefit from the increased current. Flowing water enhances the transport of fine organic particles, which support collector-feeder organisms (8) and indicates that flow and resource availability influence biodiversity. In contrast, transect 5 was predominantly made up of sand and silt and displayed low flow velocity. This could mean reduced habitat stability, lower light penetration, and decreased oxygen exchange limit diversity regardless of depth.

The formation of a mid-channel bar at Transect 3 (see Figure 2.1) indicates how depositional landforms can influence biodiversity, by affecting flow patterns and submerged area at multiple sampling points. This demonstrates that physical landforms have an effect on biodiversity as well as depth. These findings further reinforce the sensitivity of these organisms as bioindicators, as

their distribution depends on a range of abiotic factors rather than just one environmental gradient.

Community composition also varied among transects. Across all sampling sites, the macroinvertebrate community was dominated by aquatic insect nymphs, followed by aquatic worms and aquatic insect larvae, while adult aquatic insects and freshwater crustaceans and mollusks were found less frequently. The abundance of aquatic insect nymphs across most transects suggests that the stream provided suitable conditions for freshwater macroinvertebrates. Differences in the abundance of the six macroinvertebrate taxonomic groups among transects further suggest that flow velocity and substrate composition, rather than water depth alone, had a greater influence on macroinvertebrate community structure.

3.4 Influence of other abiotic factors

Depth in streams is closely correlated with flow velocity and substrate type. Shallow riffle areas typically have higher flow velocity and larger substrate, while deeper areas have less turbulent flow and finer sediment. Dissolved oxygen

concentration was not directly measured in this experiment but may also vary across the stream and influence macroinvertebrate diversity.

Differences in substrate type also acted as a confounding factor. Macroinvertebrate distribution depends heavily on substrate stability and complexity rather than depth alone, limiting the ability to isolate depth as the independent variable. Previous studies have shown that substrate composition is an important factor influencing the distribution of benthic macroinvertebrate communities since stable and coarse substrates provide attachment surfaces and stability from disturbance (10).

Substrate heterogeneity across transects also demonstrates that other abiotic factors play a crucial role in determining the distribution of benthic macroinvertebrates within stream ecosystems.

Overall, the results suggest that water depth alone was not a strong predictor of benthic macroinvertebrate diversity at the study site and that biodiversity patterns were more strongly influenced by a combination of environmental factors.

freshwater stream ecosystems cannot be explained by water depth alone.

4. CONCLUSIONS

4.1 Principles and generalizations

Water depth showed a weak positive relationship with benthic macroinvertebrate taxonomic group diversity ($r = 0.3056$). However, this relationship was not statistically significant since $p \approx 0.46 > 0.05$. Water depth alone was not a strong determinant of biodiversity within this study area and benthic macroinvertebrate diversity appears to be influenced by multiple interacting environmental factors rather than a single abiotic variable. These findings suggest that biodiversity patterns within

4.2 Exceptions / Problems

This investigation showed a correlational relationship; however, correlation does not imply causation. Several factors may have influenced the validity of the results.

Firstly, this investigation assumed that water depth was the main factor affecting biodiversity, without fully accounting for other confounding factors or the distinction between the realized and

fundamental niche. The absence of species at certain depths may have been due to biotic interactions such as competition or predation rather than abiotic factors.

Secondly, variation in substrate composition and flow velocity across the five transects may have influenced diversity, limiting the isolation of water depth as the independent variable. This was clearly seen from the relatively high biodiversity observed in the shallow riffle habitats and lower biodiversity in areas dominated by sand and silt.

In addition, some depth ranges had only two replicates while those with one were excluded from statistical analysis, reducing the sample size from $n = 10$ to $n = 8$. Unequal replication may have overemphasized certain depth ranges and allowed anomalies to influence the observed correlation.

Finally, the depth range investigated (3.0–42.9 cm) was relatively narrow and may not have produced sufficiently contrasting conditions to detect a clear relationship between water depth and biodiversity.

4.3 Theoretical/ Practical implications

These findings support ecological theories such as the River Continuum Concept which suggest that freshwater communities are influenced by multiple interacting environmental factors rather than a single abiotic variable (9). This demonstrates that benthic macroinvertebrate diversity is shaped by a combination of factors, including water depth, substrate composition and flow velocity, reinforcing the value of benthic macroinvertebrates as bioindicators since their distribution responded to variations in habitat conditions. The study highlights the importance of considering multiple habitat characteristics when assessing freshwater ecosystem health, suggesting that stream biodiversity monitoring and conservation programs should consider factors such as substrate

composition, flow velocity and habitat complexity rather than relying solely on water depth.

4.4 Conclusions and recommendations

The hypothesis which predicted a negative correlation between water depth and benthic macroinvertebrate taxonomic group diversity was not supported due to the weak positive relationship observed between water depth and biodiversity ($r = 0.3056$). This relationship was not statistically significant ($p \approx 0.46 > 0.05$), therefore the null hypothesis could not be rejected. Based on the results, water depth alone was not a major determinant of benthic macroinvertebrate diversity within the study area. Future investigations should increase the number of replicates within each depth category and sample a wider depth range to increase environmental variation. Additionally, abiotic variables such as dissolved oxygen concentration and flow velocity should be measured directly, and substrate composition should be standardized where possible to better isolate the effect of water depth on biodiversity. These improvements would increase the reliability and validity of future investigations.

5. ACKNOWLEDGMENTS

The author would like to thank Mrs. Corrie Wales and Mr. John Burrell for their guidance and feedback throughout this investigation. The author would like to thank the staff and organizers of the CreTech 2026 program for providing the opportunity and support to conduct this research. This paper was adapted from research originally conducted as part of the author's International Baccalaureate Biology Internal Assessment

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GraphBERT4FakeNews: Graph-aware Bidirectional Transformer Learning for English Fake News Detection

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ABSTRACT

The rapid dissemination of fake news through online news platforms and social media has become a major challenge, significantly influencing public opinion, political decision-making, and social stability. Recent fake news detection methods have achieved promising performance using deep contextual language models such as Bidirectional Encoder Representations from Transformers (BERT). However, most existing approaches process news articles independently and primarily focus on textual semantics while overlooking structural relationships among related news articles. Consequently, valuable graph-based information, including semantic similarity, shared entities, common publishers, and topical relationships, remains underutilized. This paper proposes GraphBERT4FakeNews, a graph transformer framework that jointly learns contextual semantic representations and graph structural information for English fake news detection. First, BERT generates contextualized embeddings from news articles. A news graph is then constructed by connecting semantically related articles according to contextual similarity. Subsequently, a GraphBERT encoder performs graph-aware self-attention to capture both local and long-range structural dependencies without relying on conventional graph convolution operations. Finally, a classification layer predicts whether a news article is genuine or fake. The proposed framework is evaluated on the publicly available FakeNewsNet benchmark, including the GossipCop and PolitiFact datasets. Experimental results demonstrate that GraphBERT4FakeNews effectively integrates semantic understanding with graph structural reasoning, leading to improved fake news detection performance compared with conventional language models and graph neural network approaches.

Keywords: Fake News Detection, GraphBERT, BERT, Graph Neural Network, Graph Transformer, FakeNewsNet

1. INTRODUCTION

The widespread adoption of online news platforms and social media has fundamentally transformed how people access and disseminate information. Although digital communication enables rapid information sharing, it also accelerates the propagation of fake news, which often spreads faster than verified information due

to its sensational content and emotional appeal [1]. Fake news has been shown to influence public opinion, financial markets, public health, and political elections, making automatic fake news detection an increasingly important research problem [2].

Recent advances in natural language processing have significantly improved fake news detection through pretrained language

models, particularly Bidirectional Encoder Representations from Transformers (BERT) [3]. By learning bidirectional contextual representations, BERT effectively captures semantic relationships among words and sentences, enabling superior textual understanding compared with conventional recurrent neural networks and convolutional neural networks [3]. Consequently, numerous fake news detection models have adopted BERT as their semantic encoder due to its ability to identify contextual inconsistencies and misleading linguistic patterns [4]. Nevertheless, BERT-based approaches primarily focus on the semantic representation of individual news articles and rarely consider relationships among multiple news articles.

Graph Neural Networks (GNNs) have recently attracted considerable attention because they naturally model relational information among interconnected objects [5]. In fake news detection, graph structures can represent semantic similarity, shared entities, publisher relationships, or topical connections among news articles [6]. Existing GNN-based methods, including Graph Convolutional Networks (GCNs) and Light Graph Convolutional Networks (LightGCN), aggregate information from neighboring nodes to enhance representation learning [5] [7]. However, these methods mainly perform local neighborhood aggregation, which limits their capability to capture long-range dependencies across complex news graphs. Furthermore, repeated graph convolution

operations often introduce the over-smoothing problem, causing node representations to become increasingly indistinguishable as network depth increases [8].

Graph Transformers have recently emerged as an effective alternative by integrating Transformer self-attention into graph representation learning. Unlike conventional graph convolution methods, Graph Transformers directly model global dependencies among graph nodes through self-attention while preserving structural information via graph-aware positional encodings [9]. GraphBERT further extends this concept by combining contextual language representations with graph structural learning, enabling simultaneous modeling of textual semantics and graph topology [10].

Motivated by these observations, this paper proposes GraphBERT4FakeNews, a novel graph transformer framework for English fake news detection. The proposed framework first employs BERT to generate contextual semantic embeddings from news articles. A semantic news graph is subsequently constructed based on contextual similarity among articles. GraphBERT then performs graph-aware self-attention over the constructed graph to capture both local neighborhood information and global structural dependencies. Finally, a multilayer classification network predicts whether each article is real or fake.

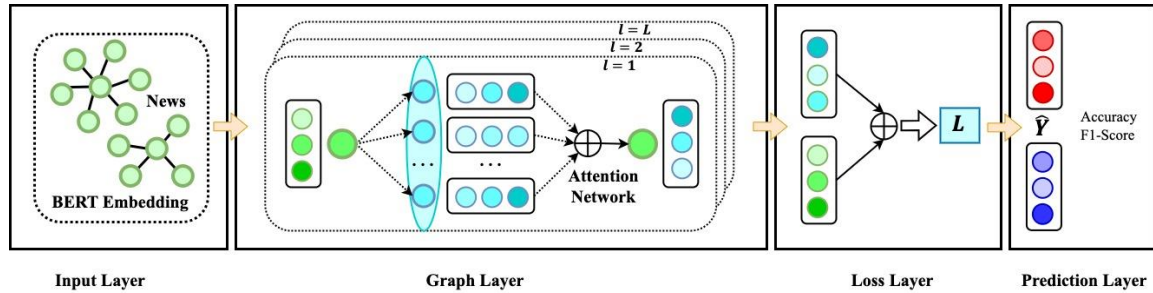


Figure 1. The architecture of the proposed GraphBERT4FakeNews.

Compared with existing BERT-based and graph neural network-based methods, GraphBERT4FakeNews provides three major advantages. First, it jointly learns semantic representations and graph structural information within a unified framework. Second, graph transformer attention effectively captures long-range relationships without relying on repeated neighborhood aggregation. Third, graph-aware representation learning improves the robustness and discriminative capability of fake news detection.

The main contributions of this paper are summarized as follows:

1. We propose GraphBERT4FakeNews, a novel graph transformer framework that integrates contextual language understanding with graph representation learning for fake news detection.
2. We construct a semantic news graph from contextual BERT embeddings, enabling explicit modeling of relationships among news articles.
3. We employ GraphBERT to learn graph-aware contextual representations

through transformer self-attention, effectively capturing both local and global structural dependencies.

4. Extensive experiments on the FakeNewsNet benchmark, including the GossipCop and PolitiFact datasets, demonstrate that the proposed framework consistently improves fake news detection performance over representative deep learning and graph-based baselines.

2. METHODOLOGY

The overall architecture of the proposed GraphBERT4FakeNews framework is illustrated in Figure 1.

2.1 Text Preprocessing

The text preprocessing stage aims to prepare English news articles for semantic representation learning while preserving the contextual information required by the BERT model. Unlike conventional Natural Language Processing (NLP) approaches, the proposed framework does not perform stop-word removal or stemming because these operations may remove useful contextual information learned during BERT pretraining [3].

Let the dataset be represented as:

$$D = \{(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)\}, \quad (1)$$

where x_i denotes the i -th news article, $y_i \in \{0,1\}$ represents the corresponding class label (0: real news, 1: fake news), and n is the total number of news articles.

First, news articles with missing or duplicate information are removed to improve the quality of the dataset. Each remaining article is then normalized by converting all characters to lowercase and removing unnecessary whitespace. The normalized text is expressed as:

$$x_i' = \text{Normalize}(x_i), \quad (2)$$

where $\text{Normalize}(\cdot)$ denotes the text normalization function.

Next, the normalized news article is tokenized using the BERT WordPiece tokenizer [3]. The token sequence is represented as:

$$T_i = \{t_1, t_2, \dots, t^L\}, \quad (3)$$

where t_j denotes the j -th token and L is the sequence length. The special tokens [CLS] and [SEP] are appended to the beginning and end of each sequence, respectively. Finally, all token sequences are padded or truncated to a fixed maximum sequence length before being forwarded to the BERT embedding layer.

The proposed preprocessing strategy preserves the semantic characteristics of news articles while ensuring compatibility with the pretrained BERT model. Consequently, high-quality contextual representations can be learned and subsequently utilized for semantic graph

construction and GraphBERT representation learning.

2.2 BERT Semantic Embedding

After text preprocessing, each news article is converted into contextual semantic representations using the Bidirectional Encoder Representations from Transformers (BERT). Unlike conventional word embedding methods such as Word2Vec or GloVe, BERT generates contextual embeddings by considering both preceding and succeeding words simultaneously, enabling a better understanding of the semantic meaning of news content [3].

Let the tokenized news article be represented as:

$$T_i = \{t_1, t_2, \dots, t^L\}, \quad (4)$$

where L denotes the sequence length.

The token sequence is then forwarded to the pretrained BERT model to obtain contextual embeddings:

$$H_i = \text{BERT}(T_i), \quad (5)$$

where H_i denotes the contextual embedding matrix generated by BERT.

The embedding corresponding to the [CLS] token is extracted as the semantic representation of the entire news article:

$$h_i = H_i(\text{CLS}), \quad (6)$$

where h_i is the sentence-level embedding used to represent the semantic characteristics of the news article.

The generated semantic embeddings are subsequently utilized for semantic graph construction in the next stage.

2.3 Semantic Graph Construction

To model relationships among semantically similar news articles, a semantic graph is constructed from the BERT embeddings. Let the graph be defined as:

$$G = (V, E), \quad (7)$$

where V represents the set of news nodes and E denotes the set of graph edges.

Each node corresponds to one news article, while edges are established according to the cosine similarity between two semantic embeddings.

$$S(i, j) = \frac{(h_i \cdot h_j)}{(\|h_i\| \|h_j\|)}, \quad (8)$$

where $S(i, j)$ denotes the cosine similarity between news articles i and j .

An edge is created if the similarity exceeds a predefined threshold τ from 0.1 to 0.5 with an interval 0.1 to determine the optional graph structure.

$$A(i, j) = \begin{cases} 1, & \text{if } S(i, j) \geq \tau \\ 0, & \text{otherwise} \end{cases}, \quad (9)$$

where A denotes the adjacency matrix of the semantic graph.

The resulting graph enables structurally related news articles to exchange semantic information during GraphBERT learning.

2.4 GraphBERT Encoder

Given the semantic graph, GraphBERT is employed to learn graph-aware contextual representations through the Transformer self-attention mechanism [10]. Unlike Graph Convolutional Networks (GCNs), GraphBERT captures both local and global structural dependencies without repeated neighborhood aggregation.

For each graph node, query, key, and value vectors are computed as:

$$Q = HW_Q, \quad (10)$$

$$K = HW_K, \quad (11)$$

$$V = HW_V, \quad (12)$$

where H denotes the node feature matrix, and W_Q , W_K , and W_V are learnable projection matrices.

The attention score is calculated as:

$$\text{Attention}(Q, K, V) = \text{Softmax}\left(\frac{QK^T}{\sqrt{d}} + B\right)V, \quad (13)$$

where d is the embedding dimension, and B represents the graph structural bias encoding.

The final node representation is obtained by:

$$Z = \text{GraphBERT}(G, H), \quad (14)$$

where Z is the graph-aware embedding matrix learned by the GraphBERT encoder.

The learned node representations integrate both semantic information from BERT and structural relationships from the semantic graph.

2.5 Fake News Classification

The graph-aware embedding of each news article is forwarded to a fully connected layer followed by the Softmax classifier.

The prediction probability is computed as:

$$\hat{y} = \text{Softmax}(WZ + b), \quad (15)$$

where W and b denote the trainable weight matrix and bias vector, respectively.

The predicted label is determined by:

$$\hat{y} = \text{argmax}(\text{Softmax}(WZ + b)), \quad (16)$$

where the output class is either Real News or Fake News.

2.6 Model Optimization

The proposed GraphBERT4FakeNews framework is trained using the Cross-Entropy

loss function to minimize the difference between predicted and true labels.

The loss function is defined as:

$$L = -\sum y \log(\hat{y}), \quad (17)$$

where y is the ground-truth label and $\hat{y}$ is the predicted probability.

Model parameters are optimized using the AdamW optimizer with backpropagation. During training, dropout is applied to reduce overfitting, while early stopping is adopted to prevent performance degradation on the validation set.

3. RESULTS AND DISCUSSION

This section evaluates the effectiveness of the GraphBERT4FakeNews framework. Experiments are conducted on two public fake news datasets, PolitiFact and GossipCop, using Accuracy (ACC) and F1-score (F1) as the evaluation metrics. The proposed model is compared with several representative fake news detection methods, followed by an ablation study and hyperparameter analysis.

3.1 Datasets

Experiments were conducted on the publicly available FakeNewsNet benchmark, which consists of two widely used datasets: PolitiFact and GossipCop [6]. PolitiFact mainly contains political news articles, whereas GossipCop focuses on entertainment and celebrity news. Each dataset contains both real and fake news articles with verified labels. The datasets are divided into training, validation, and test sets using a 7:1:2 ratio. All experiments are independently repeated three times, and the average results are

reported. The statistical information of the datasets is summarized in Table 1.

Table 1. Statistics of the PolitiFact and GossipCop datasets.

Datasets	PolitiFact	GossipCop
#News	314	5,464
#True News	157	2,732
#Fake News	157	2,732
#Nodes	41,054	314,262
#Edges	40,740	308,798

3.2 Baselines

To evaluate the effectiveness of the proposed framework, GraphBERT4FakeNews was compared with several representative fake news detection methods.

1. TruthFinder [11] is an early unsupervised fake news detection method that estimates news credibility through iterative source reliability analysis.

2. GTUT [12] is a graph-based fake news detection model that progressively propagates labels across the news graph from an initial seed set.

3. SAFE [13] is a multimodal framework that jointly learns textual and visual representations for fake news.

4. EANN [14] employs adversarial learning to extract event-invariant textual and visual features for detecting fake news.

5. GAMC [15] is a graph contrastive learning approach that improves graph representation by combining node masking,

edge dropping, graph reconstruction, and contrastive learning.

3.3 Overall performance

Table 2 compares the proposed GraphBERT4FakeNews with the baseline methods. GraphBERT4FakeNews achieves the highest performance on both PolitiFact and GossipCop.

Table 2. Performance comparison between GraphBERT4FakeNews and baseline methods.

Methods	PolitiFact		GossipCop	
	ACC.	F1.	ACC.	F1.
TruthFinder	0.581	0.573	0.668	0.669
GTUT	0.776	0.767	0.771	0.744
SAFE	0.793	0.775	0.832	0.811
EANN	0.804	0.798	0.836	0.813
GAMC	0.838	0.831	0.946	0.943
GraphBERT4FakeNews	0.851	0.844	0.952	0.949

On the PolitiFact dataset, GraphBERT4FakeNews achieved an Accuracy of 0.851 and an F1-score of 0.844, outperforming the strongest baseline (GAMC) by 1.3% and 1.3%, respectively. Similarly, on the GossipCop dataset, the proposed model obtained an Accuracy of 0.952 and an F1-score of 0.949, which are higher than those of GAMC.

The performance improvement demonstrates that combining contextual semantic representations from BERT with graph-aware representation learning effectively captures both textual semantics and structural relationships among news articles, leading to more accurate fake news detection.

3.4 Ablation study

To investigate the contribution of each component, an ablation study was conducted by progressively removing the GraphBERT module while retaining only BERT

embeddings or graph representation learning. The results are presented in Table 3.

Table 3. Ablation study of GraphBERT4FakeNews.

Datasets	PolitiFact	GossipCop
	ACC.	ACC.
BERT	0.840	0.943
Graph	0.847	0.946
GraphBERT4FakeNews	0.851	0.952

Using only BERT achieved competitive performance because of its strong contextual semantic representation capability. Incorporating graph structural information further improved the classification accuracy by exploiting semantic relationships among news articles. The complete GraphBERT4FakeNews framework consistently achieved the best performance on both datasets, demonstrating that jointly learning semantic and structural

representations is beneficial for fake news detection.

3.5 Hyperparameter setting

Figure 2 presents the effect of the BERT embedding dimension and the number of GraphBERT layers on the classification accuracy of the GraphBERT4FakeNews.

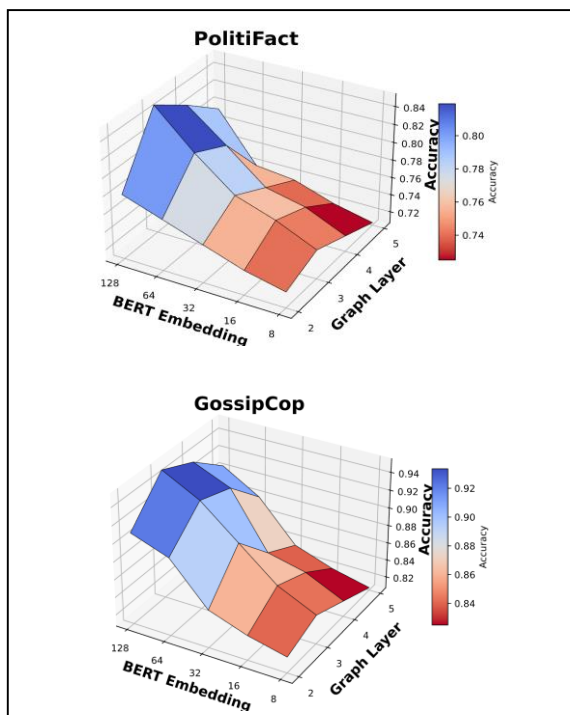


Figure 2. Effect of BERT embedding dimension and Graph layers on PolitiFact and GossipCop datasets.

For both the PolitiFact and GossipCop datasets, the classification accuracy generally improves as the embedding dimension increases. The best performance is achieved with an embedding dimension of 128 and three Graph layers. Increasing the number of layers beyond three provides only marginal improvements while increasing computational complexity. Therefore, these hyperparameter settings are adopted in all subsequent experiments.

4. CONCLUSIONS

This paper proposes the GraphBERT4FakeNews, a graph transformer framework for English fake news detection that integrates BERT semantic embeddings with graph-aware representation learning. A semantic graph is first constructed from contextual news embeddings, and GraphBERT is subsequently employed to capture both semantic and structural relationships among news articles. Experimental results on the PolitiFact and GossipCop datasets demonstrate that the proposed framework consistently outperforms representative baseline methods in terms of Accuracy and F1-score.

The experimental findings confirm that jointly learning contextual semantics and graph structural information significantly improves fake news detection performance. Future work will investigate heterogeneous graph construction by incorporating publisher, user, and temporal information, as well as larger multilingual fake news datasets to further improve model generalization.

5. ACKNOWLEDGMENTS

The authors thank Major of Information Technology and Digital Business, Faculty of Business Administration, Rajamangala University of Technology Krungthep, Bangkok, Thailand for their support.

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BERTGRU4Sentiment: Bidirectional Encoder Representations from Transformers with Gated Recurrent Unit for Multilingual Sentiment Analysis

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ABSTRACT

This study proposes BERTGRU4Sentiment, a deep learning model that combines fine-tuned Bidirectional Encoder Representations from Transformers (BERT) with a Gated Recurrent Unit (GRU) for multilingual sentiment analysis. The proposed model is evaluated on four benchmark datasets: Wongnai (Thai), Amazon Reviews (English), Twitter/X (English), and IMDB (English), covering both three-class (negative, neutral, positive) and two-class (negative, positive) classification tasks. To address class imbalance, a mixed over- and under-sampling strategy is applied to all datasets. Results demonstrate that BERTGRU4Sentiment consistently outperforms traditional baseline models including Decision Tree, Random Forest, XGBoost, and LSTM across all datasets, achieving accuracy of 69.49% on Wongnai, 93.67% on Amazon Reviews, 71.73% on Twitter, and 83.97% on IMDB. The findings confirm that BERTGRU4Sentiment enables richer contextual feature extraction, and the proposed architecture is effective for multilingual sentiment classification tasks.

Keywords: Sentiment Analysis, BERT, GRU, Deep Learning, Natural Language Processing, Multilingual

1. INTRODUCTION

Sentiment analysis, also known as opinion mining, is a natural language processing (NLP) task that aims to identify and extract subjective information from text data. With the exponential growth of user-generated content on social media platforms, e-commerce websites, and review sites, automated sentiment analysis has become increasingly important for businesses and researchers alike [1] [2].

Traditional machine learning approaches such as Decision Tree, Random Forest, XGBoost, and LSTM methods combined with term frequency-inverse document frequency (TF-IDF) features have been widely used for sentiment classification. However, these methods often fail to capture

contextual relationships and long-range dependencies within text sequences [3].

The introduction of transformer-based pre-trained language models, particularly BERT, has revolutionized NLP tasks by providing deep contextual word representations [4]. Meanwhile, (GRU) have shown strong capability in modeling sequential patterns in text data [5]. Combining these two approaches through fine-tuning offers the potential to leverage both contextual understanding and sequential feature learning.

This study presents BERTGRU4Sentiment, a model that fine-tunes BERT and (GRU) [6] [7] [8] [9] jointly for multilingual sentiment analysis. The model is evaluated on four diverse datasets,

covering Thai and English languages, and compared against four baseline methods to demonstrate its effectiveness.

2. MATERIALS AND METHODS

2.1 Datasets

Four publicly available datasets are used in this study: (1) Wongnai, a Thai-language restaurant review dataset with star ratings 0–4, where ratings 0–1 are labeled negative, rating 2 neutral, and ratings 3–4 positive; (2) Amazon Reviews, an English-language product review dataset with scores 1–5, where scores 1–2 are labeled negative, score 3 neutral, and scores 4–5 positive; (3) Twitter/X, an English-language tweet dataset with pre-labeled sentiment classes (negative, neutral, positive); and (4) IMDB, an English-language movie review dataset with binary sentiment labels (negative, positive). Unlike Wongnai, Amazon, and Twitter/X, which provide rating scales or pre-labeled neutral categories that can be mapped to a three-class scheme, the IMDB dataset is natively annotated with only binary sentiment labels

(positive/negative) in its original release, with no neutral category available. The binary setting is therefore retained to preserve the integrity of the original annotations rather than introducing artificial neutral labels.

The dataset selection reflects the study's dual objective: to develop a model applicable to the Thai context, given the target deployment environment, while also validating the architecture's generalizability across English text of varying genres and formality levels (product reviews, social media, and movie reviews). This design allows the proposed model to be evaluated both for language-specific performance (Thai) and for cross-genre robustness (English). Table 1 summarizes the dataset statistics after balancing, and Table 2 shows sample texts from each dataset.

Table 1. Dataset statistics after balancing.

Dataset	Language	Classes	Samples/Class	Total
Wongnai	Thai	3	5,000	15,000
Amazon	English	3	1,000	3,000
Twitter/X	English	3	5,000	15,000
IMDB	English	2	5,000	10,000

Table 2. Sample texts from each dataset and sentiment class.

Dataset	Class	Example text
Wongnai	Negative	ร้านข้าวหมูกรอบที่ผมมักฝากท้องไว้ ที่โดดเด่นคือ ได้รับป้ายเปิบพิศดาร จุดเด่นร้านนี้คือ ราคาถูก ทุกอย่างราคา 25 บาท นั่งกินที่ไหนก็ได้ แต่รสชาติไม่ได้เรื่อง น้ำซุซจืดชืดๆ ไม่เข้มข้น
	Neutral	ร้านอาหารใหญ่มากกกกกก เลี้ยวเข้ามาเจอห้องน้ำก่อนเลย เออแปลกดี ห้องทานหลักๆอยู่ชั้น 2 มีกาแฟน้ำผึ้ง ซึ่งก็แค่เอาน้ำผึ้งมาราด แพงเวอร์ อย่าสั่งเลย
	Positive	อาหารที่นี่เป็นอาหารจีนแคะที่ทำกินยากในบ้านเรา ตัวร้านตั้งอยู่ที่ถนนพหลโยธินสาย 3 รสชาติดีมาก ราคาคุ้มค่า แนะนำอย่างยิ่ง
Amazon	Negative	I bought 2 of those SanDisk 32 GB microSD, used them on my Galaxy Note and Galaxy S4. First one, my phone started saying it was removed, then recognize it again, then died. I thought it's just bad luck.

	Neutral	It works, but file writes are a bit slower than expected on a USB3 reader. Also, both reads and writes are FASTER with the card inside the standard-size SD adapter (15 MB/s vs 10 write; 45 MB/s vs 22 read).
	Positive	No issues. Good price, works flawless in my Samsung S4! Normal SanDisk quality! That is why I go with this brand and only this brand.
Twitter/X	Negative	Sooo SAD I will miss you here in San Diego!!!
	Neutral	I'd have responded, if I were going
	Positive	2am feedings for the baby are fun when he is all smiles and coos
IMDB	Negative	Basically there's a family where a little boy (Jake) thinks there's a zombie in his closet & his parents are fighting all the time. This movie is slower than a soap opera... and suddenly, Jake decides to become a man.
	Positive	One of the other reviewers has mentioned that after watching just 1 Oz episode you'll be hooked. They are right, as this is exactly what happened with me. The first thing that struck me about Oz was its brutal setting.

2.2 Data Preprocessing

Text preprocessing is performed using a language-aware pipeline. For Thai text (Wongnai dataset), PyThaiNLP library is used for word tokenization and Thai stopword removal. For English text (Amazon, Twitter, IMDB), NLTK library is used for word tokenization and English stopword removal. A unified preprocessing function is implemented to automatically detect the language by analyzing the proportion of Thai Unicode characters in the text. URLs and special characters are removed from all texts prior to tokenization.

2.3 Class Imbalance Handling

To address class imbalance present in all datasets, a mixed sampling strategy is applied. Classes with fewer samples than the target count are oversampled with replacement (oversampling), while classes exceeding the target count are randomly downsampled (undersampling). This approach ensures equal class representation while preserving sufficient training samples [10].

2.4 Proposed Model: BERTGRU4Sentiment

The proposed BERTGRU4Sentiment model consists of three main components:

(1) BERT Encoder: WangchanBERTa (airesearch/wangchanberta-base-att-spm-uncased) [11] is used for the Wongnai dataset, while Multilingual BERT (bert-base-multilingual-cased) [12] is used for the Amazon, Twitter, and IMDB datasets. Unlike previous approaches that use BERT solely as a static feature extractor, this study fine-tunes BERT jointly with GRU during training [13].

(2) Bidirectional GRU Layer: A bidirectional GRU with 128 hidden units and 2 layers processes the token embedding sequences output by BERT (shape: batch $\times$ 128 $\times$ 768). The bidirectional architecture captures both forward and backward contextual dependencies.

(3) Fully Connected Layers: Two dense layers (128 and 64 units with ReLU activation) with dropout regularization (rate = 0.3) produce the final class probabilities via softmax activation.

The model was trained using AdamW optimizer with a learning rate of $2e-5$, weight decay

of 0.01, and a linear learning rate scheduler with warmup steps equal to 10% of total training steps. Gradient clipping (max norm 1.0) is applied to prevent exploding gradients. Early stopping with patience of 3 epochs is used to prevent overfitting. All experiments are conducted on NVIDIA A100 GPU with batch size 16 and maximum 10 epochs.

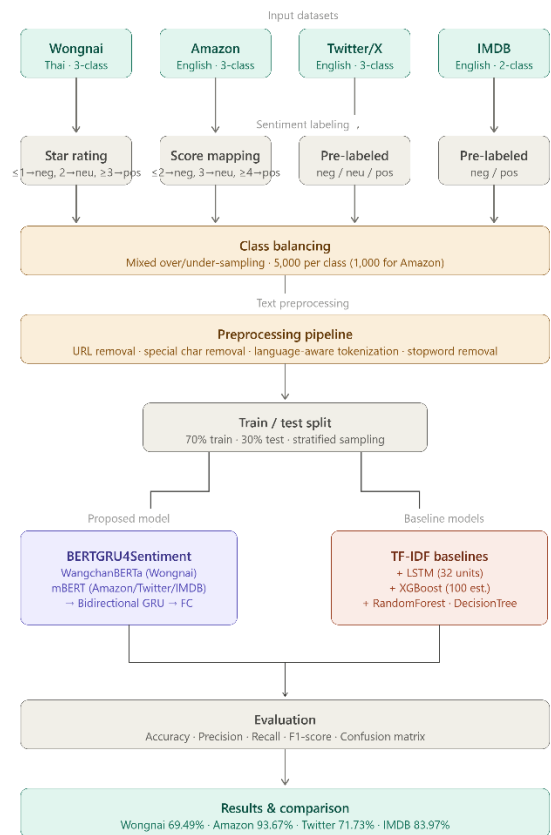


Figure 1. BERTGRU4Sentiment Architecture

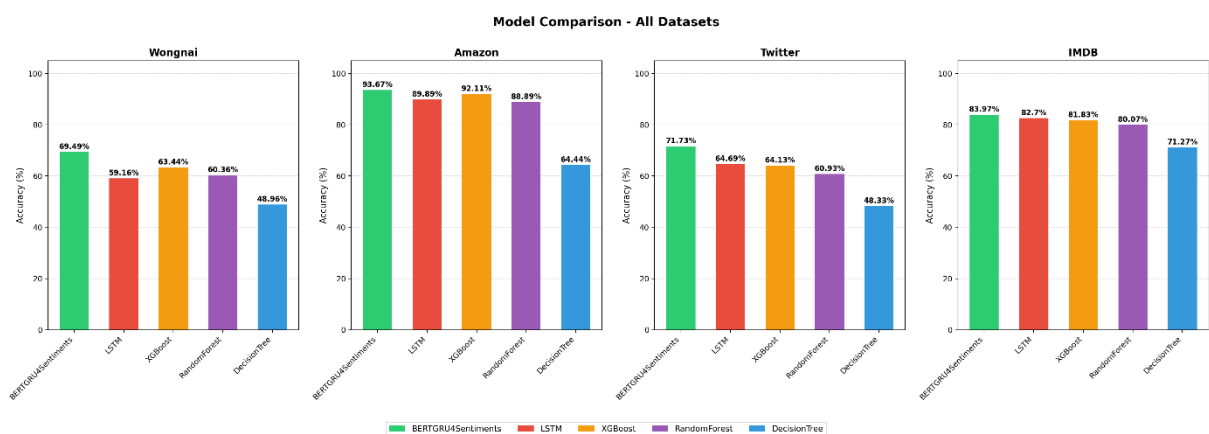


Figure 2. Model accuracy comparison across all datasets.

2.5 Baseline Models

Four baseline models are implemented for comparison: (1) Decision Tree: Decision Tree classifier (max depth 10); (2) Random Forest: TF-IDF

features with Random Forest (100 estimators, max depth 10); (3) XGBoost: TF-IDF features with XGBoost classifier [14] (100 estimators, max depth 6); and (4) LSTM: TF-IDF features combined with LSTM (32 units). All baseline models use the same

Model	Wongnai	Amazon	Twitter	IMDB
Decision Tree	48.96%	64.44%	48.33%	71.27%
Random Forest	60.36%	88.89%	60.93%	80.07%
XGBoost	63.44%	92.11%	64.13%	81.83%
LSTM	59.16%	89.89%	64.69%	82.70%
BERTGRU4Sentiment	69.49%	93.67%	71.73%	83.97%

preprocessed text and class-balanced data as the proposed model.

2.6 Evaluation Metrics

Model performance is evaluated using four standard metrics: Accuracy, Precision, Recall, and F1-score. For multi-class classification, per-class scores are reported alongside overall accuracy. All experiments used a 70/30 train-test split with stratified sampling. Accuracy is reported as the primary metric for overall model comparison in Table 3, as it is directly comparable across models and datasets. However, since class imbalance can make accuracy alone insufficient, precision, recall, and F1-score are additionally reported at the per-class level (Section 3.2) to provide a more complete assessment of model behavior, particularly for the minority or more ambiguous classes such as "neutral."

3. RESULTS AND DISCUSSION

3.1 Overall Performance Comparison

Table 3 presents the comprehensive performance comparison across all models and datasets. The proposed model achieves the highest accuracy on all four datasets: Wongnai (69.49%), Amazon (93.67%), Twitter (71.73%), and IMDB (83.97%). Figure 1 illustrates the accuracy comparison as a bar chart.

Table 3. Overall accuracy comparison of all models across four datasets.

3.2 Analysis by Dataset

Wongnai (Thai, 3-class)

BERTGRU4Sentiment achieves 69.49% accuracy on the Wongnai Thai dataset, outperforming all baseline models. The negative class achieves the highest F1-score (0.8615) while the neutral class remains most challenging (F1 = 0.5730) due to its inherently ambiguous nature. This demonstrates the effectiveness of WangchanBERTa fine-tuning for Thai sentiment analysis, where the model captures language-specific nuances that TF-IDF-based methods cannot represent.

As shown in Figure 3, the diagonal values of the confusion matrix ($1,284 + 863 + 980 = 3,127$ out of 4,500 test samples) confirm that the model correctly classifies the majority of samples across all three classes, with the negative class showing the strongest prediction confidence.

Amazon Reviews (English, 3-class)

On Amazon Reviews, BERTGRU4Sentiment achieves the best accuracy of 93.67%. The model performs exceptionally across all three classes, with F1-scores of 0.9465 (negative), 0.9420 (neutral), and 0.9215 (positive). Despite the limited dataset size after balancing (1,000 samples per class), the proposed model demonstrates strong generalization.

As shown in Figure 3, the diagonal values ($283 + 284 + 276 = 843$ out of 900 test samples) indicate that the model correctly classifies nearly

all samples, demonstrating strong generalization despite the limited dataset size after balancing (1,000 samples per class).

Twitter/X (English, 3-class)

BERTGRU4Sentiment achieves 71.73% accuracy on Twitter/X, the highest among all models. Twitter data presents unique challenges including informal language, hashtags, and abbreviations. The positive class achieves the best F1-score (0.7808) while the neutral class remains challenging (F1 = 0.6359).

As shown in Figure 3, the diagonal values (1,070 + 952 + 1,206 = 3,228 out of 4,500 test samples) confirm that the model correctly identifies the majority of tweets across all three classes, with the positive class showing the highest prediction confidence.

IMDB (English, 2-class)

On the IMDB binary classification task, BERTGRU4Sentiment achieves 83.97% accuracy, correctly classifying 1,299 negative and 1,220 positive reviews with F1-scores of 0.8438 and 0.8353 respectively.

As shown in Figure 3, the diagonal values (1,299 + 1,220 = 2,519 out of 3,000 test samples) demonstrate that the model reliably distinguishes between negative and positive sentiments, with the negative class showing slightly higher classification accuracy.

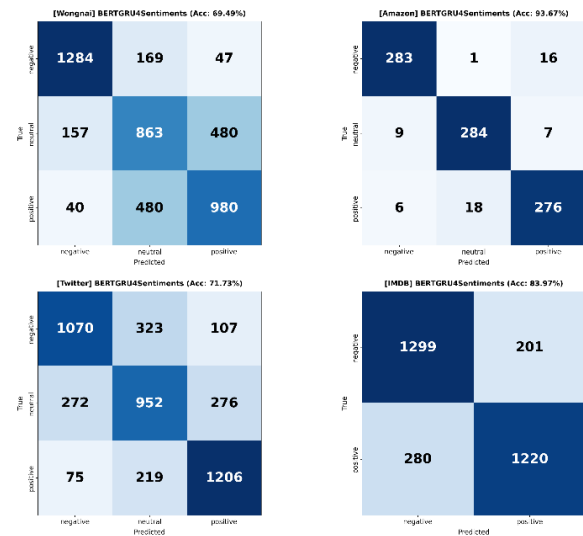


Figure 3. Confusion Matrix of BERTGRU4Sentiments

The comparatively lower accuracy on the Wongnai dataset (69.49%) can be attributed to linguistic and data-related factors. Thai lacks explicit word boundaries, making tokenization more error-prone even with a Thai-specific tokenizer. Reviews also frequently contain informal language, elongated words for emphasis, and mixed sentiment within a single review, increasing ambiguity for the neutral class. In addition, WangchanBERTa is pretrained on a smaller corpus than multilingual BERT, which may limit its contextual representation capacity. These factors help explain why the neutral class remains hardest to classify (F1 = 0.5730) and lowers overall accuracy.

Notably, dataset size alone does not determine performance. Despite having the smallest sample size (1,000 per class), Amazon achieves the highest accuracy (93.67%), suggesting label consistency and linguistic clarity matter more than data volume. Amazon's rating-to-sentiment mapping produces unambiguous labels, and its review vocabulary (e.g., "flawless," "no issues") is

more explicit than the informal, context-dependent language in Twitter or Wongnai. This indicates data quality and label consistency, rather than sample size, are the dominant factors affecting performance.

3.3 Impact of Fine-tuning

A key contribution of this work is the joint fine-tuning of BERT and GRU. Compared to using BERT as a static feature extractor, fine-tuning allows BERT to adapt its contextual representations specifically for sentiment analysis. This is particularly evident on the Wongnai and Twitter datasets. The bidirectional GRU component effectively captures sequential patterns in the BERT output token sequences, providing additional discriminative power beyond what the [CLS] token alone can offer.

3.4 Training and Validation Curves

Figure 4 shows the training and validation accuracy and loss curves across all four datasets. The training accuracy increases consistently in all datasets while the validation accuracy stabilizes in early epochs, indicating that the model converges without significant underfitting. However, the widening gap between training and validation loss in the Wongnai, Twitter, and IMDB datasets suggests mild overfitting in later epochs, which is effectively controlled by the early stopping strategy. The Amazon dataset shows the most stable convergence, consistent with its highest accuracy of 93.67%.

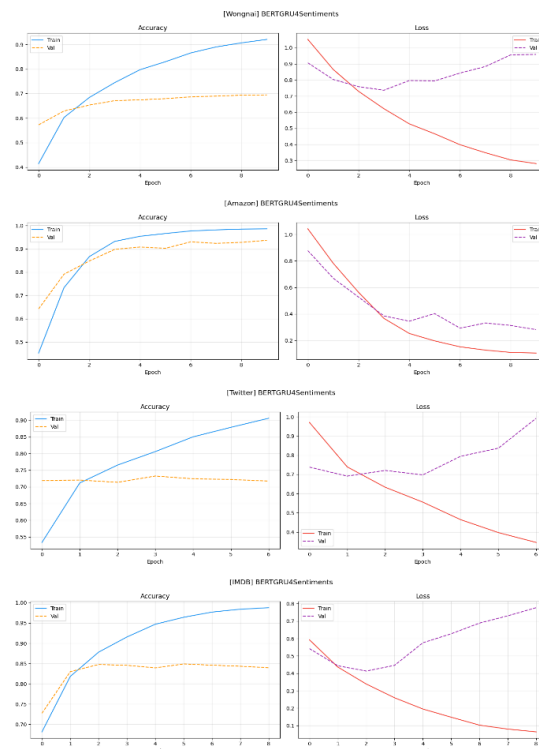


Figure 4. Training and Validation Accuracy and Loss Curves of BERTGRU4Sentiments across Four Datasets

3.5 Hyperparameter Sensitivity Analysis

A grid search is conducted over learning rate $\in \{1e-5, 2e-5, 5e-5\}$ and batch size $\in \{8, 16, 32\}$. As shown in Figure 5, on Wongnai, learning rate $2e-5$ with batch size 32 yields the highest accuracy of 66.93%, while $5e-5$ consistently degrades performance to 33.33%, indicating instability during Thai-language fine-tuning. Amazon peaks at 96.44% ($5e-5$, batch 16) but drops sharply to 66.89% at the lowest learning rate. Twitter/X remains stable across all configurations (72.76%–74.18%), and IMDB peaks at 84.33% ($5e-5$, batch 16). Overall, learning rate $2e-5$ with batch size 16 provides the most consistent performance across datasets and is adopted as the final configuration.

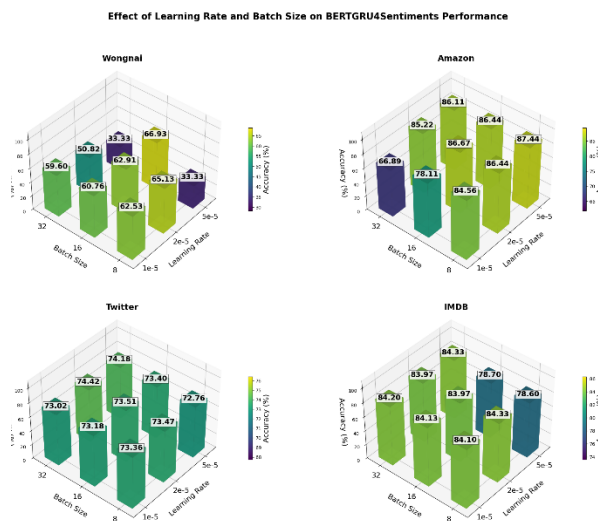


Figure 5. Effect of Learning Rate and Batch Size on BERTGRU4Sentiment Performance across Four Datasets

3.6 Error Analysis

Across all datasets, misclassification predominantly occurs at class boundaries rather than between polar opposites (e.g., negative vs. positive). For the three-class datasets (Wongnai, Amazon, Twitter/X), the confusion matrices in Figure 3 show that most errors involve the neutral class being confused with either negative or positive, reflecting the inherent ambiguity of neutral sentiment expressions, which often contain mixed or mild opinions. For example, on Wongnai, 480 neutral samples were misclassified as positive and 480 as negative, compared to only 47–169 cross-polarity errors for the negative and positive classes. On IMDB, misclassifications are more evenly distributed between the two classes (201 false positives, 280 false negatives), suggesting that binary errors are less influenced by class ambiguity and more likely caused by mixed-sentiment reviews (e.g., reviews containing both praise and criticism) or sarcasm, which BERT-based models are known to struggle with.

4. CONCLUSIONS

This study presents BERTGRU4Sentiment, a novel architecture that fine-tunes BERT and GRU jointly for multilingual sentiment analysis. The model is evaluated on four datasets covering Thai and English and demonstrates superior or competitive performance compared to four baseline models.

Future work may explore larger pre-trained models such as RoBERTa or DeBERTa, data augmentation for small datasets, and extension to other languages and domains.

5. ACKNOWLEDGMENTS

The authors thank Major of Information Technology and Digital Business, Faculty of Business Administration, Rajamangala University of Technology Krungthep, Bangkok, Thailand for their supports.

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A structured conceptual review of the Sports Dance Model (SDM): core characteristics and practical value

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ABSTRACT

The Sports Dance Model (SDM) is used in this review as an author-defined framework for organizing the technical, biomechanical, interpersonal, psychological, and artistic requirements of competitive ballroom dance. To strengthen the scientific basis of the framework, we conducted a structured conceptual review of PubMed, Crossref-indexed records, Semantic Scholar, citation chains, and official World DanceSport Federation (WDSF) documents. Searches covered 2010 to 27 July 2026 and used five concept blocks: DanceSport terminology, technique and biomechanics, partner interaction, judging and artistic presentation, and training or intelligent assessment. Twenty-two sources met the eligibility criteria, including 20 peer-reviewed studies and two WDSF documents. The synthesis supports six interrelated dimensions: technical standardization, biomechanical rationality, partner coordination, the combined sporting and artistic character of DanceSport, hierarchical organization, and scenario-dependent adaptation. The evidence is strongest for Standard-dance biomechanics, especially Waltz and Viennese Waltz, and for psychological partnership in Chinese DanceSport samples. Evidence remains thinner for cross-style generalization, artistic-expression mechanisms, and DanceSport-specific artificial-intelligence assessment. SDM should therefore be treated as a provisional, evidence-organizing framework rather than a universally validated model. Within these boundaries, it can support more explicit training design, clearer alignment with judging criteria, and the development of testable quantitative indicators.

Keywords: Sports Dance Model; DanceSport; conceptual review; biomechanics; partner coordination; judging; technical standardization

1. INTRODUCTION

Research background

DanceSport is an internationally regulated form of competitive partnered dance. The World DanceSport Federation (WDSF) organizes Standard and Latin disciplines, each comprising five dances, and publishes technical books for all ten styles [1]. WDSF adjudication evaluates Technical Quality, Movement to Music, Partnering Skills, and Choreography and Presentation, thereby combining technical and artistic performance criteria [2]. These rules provide a practical basis for examining how technique, biomechanics, partner interaction, and expression contribute to competitive performance.

In this review, the Sports Dance Model (SDM) is not treated as a formally validated universal model. Instead, SDM denotes an author-defined integrative framework that organizes recurring requirements identified in DanceSport rules and research. This distinction is important because the available literature contains multiple local models and measurement approaches, but no single internationally accepted SDM taxonomy.

The evidence base is dispersed across discipline-specific studies. Standard-dance research has examined Waltz and Viennese Waltz turns, spin kinematics, sway, contrary body movement, and partnering effects [4-10]. Latin-dance research has addressed Samba plantar-pressure patterns and the

physiological demands of simulated Latin competition [3, 17]. Other studies have investigated partner relationships, athlete engagement, personality matching, emotional states, conditioning, and injury patterns [11-20]. Computer-vision research shows the potential of automated dance-motion recognition and quality evaluation, although most available systems are not yet specific to competitive DanceSport [21, 22].

This fragmentation creates two practical risks. First, results from one dance style may be generalized to another despite different movement vocabularies and mechanical demands. Second, broad statements about training or judging may rely on studies that measured only a single action, discipline, or population. A defensible SDM therefore requires explicit source selection, claim-level citation matching, and clear limits on generalization.

Evidence base and research gap

Biomechanical and technical evidence

Technical evidence is concentrated in Standard dances. Studies of Waltz and Viennese Waltz have quantified turning trajectories, step length, trunk-pelvis coordination, sway, contrary body movement, and rise-and-fall partnering effects [4-10]. These studies show that inertial sensors, video tracking, and angular-velocity measures can distinguish specific movement patterns and, in some cases,

relate them to adjudicators' scores. However, their findings are movement-specific and should not be presented as direct evidence for all ten DanceSport styles.

Latin-dance evidence addresses different questions. Plantar-pressure research on Samba characterizes loading during a Latin step pattern [3], while simulated Latin competition studies document dance-specific heart-rate and perceived-exertion profiles [17]. These findings support the inclusion of mechanical loading and physical demand in the framework, but they do not validate Standard-dance footwork or Waltz mechanics. The revised synthesis therefore separates Standard and Latin evidence whenever a claim is discipline-specific.

Technology-oriented studies demonstrate that computer vision and spatiotemporal neural networks can recognize or evaluate complex dance movement [21, 22]. Their datasets and evaluation tasks are broader than competitive ballroom dance, so they are used here only to identify a future research route. They are not cited as evidence that automated SDM scoring is already valid.

Partner and psychological evidence

DanceSport partnership has been examined through qualitative interviews, scale development, mediation models, dyadic analysis, and personality research [11-15]. These studies consistently identify interpersonal perception, instrumental and

expressive ties, trust, engagement, and partner compatibility as relevant constructs. A systematic review also indicates that anxiety, stress, arousal, concentration, and mental-preparation techniques are recurring themes in DanceSport performance research [16].

The partnership evidence complements kinematic studies showing that dancing with a partner changes joint motion, step length, and rise-and-fall execution in competitive Waltz [7, 10]. Together, these findings justify treating partner coordination as both a physical interaction and a psychological relationship. Nevertheless, much of the recent psychological evidence comes from Chinese samples, which limits unqualified cross-cultural generalization.

The literature still lacks a validated, cross-disciplinary model tested across Standard and Latin styles, competition levels, cultures, and judging systems. The present review therefore develops a working conceptual framework and makes its evidential boundaries explicit rather than claiming that the framework is complete or universally established.

Scope and objectives

This review has four objectives: (1) to define SDM as a transparent working framework; (2) to synthesize evidence for its proposed dimensions while maintaining discipline-specific citation accuracy; (3) to map the framework to training, judging,

performance, and talent-development contexts; and (4) to identify testable gaps for biomechanical, psychological, and technology-assisted research.

The theoretical contribution is an evidence-organizing structure that links WDSF performance criteria with findings from movement science, sport psychology, conditioning, and dance-technology research. The framework is intended to generate hypotheses and measurement plans, not to replace discipline-specific technique systems.

The practical contribution is a clearer basis for aligning training tasks with their evidential target. Coaches can distinguish technical, biomechanical, physical, and partnership objectives; adjudicators can relate observations to defined performance components; and researchers can identify which proposed links still require empirical validation.

2. MATERIALS AND METHODS

Search strategy: We conducted a structured conceptual review on 27 July 2026. PubMed, Crossref-indexed records, and Semantic Scholar were searched, followed by backward and forward citation checking and targeted consultation of WDSF technical and adjudication documents. The publication window was January 2010 to July 2026. The main Boolean blocks combined ("DanceSport" OR "competitive ballroom dance" OR "sport ballroom dancing") with

(technique OR biomechanics OR kinematics OR balance), (partner OR partnership OR dyad OR coordination), (judging OR adjudication OR scoring OR artistic presentation), and (training OR physiology OR injury). A separate technology block combined dance with computer vision, motion recognition, artificial intelligence, and quality evaluation. The PubMed search returned 63 records before screening.

Eligibility criteria: We included English-language peer-reviewed original studies or reviews that directly examined competitive ballroom or DanceSport technique, biomechanics, partner interaction, psychology, physiological demand, injury, judging, or measurement. Official WDSF sources were included when they defined technique or adjudication standards. We excluded therapeutic or recreational dance studies without a competitive DanceSport connection, non-dance sport studies, duplicates, sources with unverifiable bibliographic information, and papers whose outcomes could not support a proposed SDM dimension.

Screening and citation verification: Titles and abstracts were screened against the eligibility criteria, duplicates were removed by DOI or title-author matching, and candidate sources were checked at the claim level. Each included reference was verified by DOI, PubMed, publisher metadata, or an official WDSF page. A source was retained

only when its actual dance style, movement, population, and outcome matched the statement it supported. Data extraction and synthesis: For each source, we recorded publication year, study design, sample or source type, DanceSport discipline, movement or construct examined, measurement method, principal finding, and direct relevance to the proposed framework. Evidence was grouped into five domains: technical-biomechanical, partner-psychological, physiological and injury-related, judging-artistic, and technology-assisted assessment. Review yield and methodological boundary: The final synthesis included 22 sources: 20 peer-reviewed studies and two official WDSF documents. Because study designs, movements, outcomes, and populations were highly heterogeneous, no pooled effect estimate or formal risk-of-bias score was calculated. The review is therefore structured and reproducible at the search and selection level, but its output is a conceptual synthesis rather than a systematic meta-analysis.

3. RESULTS AND DISCUSSION

Definition of SDM

For this review, SDM is operationally defined as a provisional framework that

organizes the observable and trainable requirements of competitive DanceSport. Its proposed components include style-specific technique, movement mechanics, physical capacity and load, partner interaction, psychological partnership, musical and artistic presentation, and competition-related decision making. The framework is derived from convergent evidence and WDSF performance criteria; it has not yet been validated as a single measurement model.

SDM has both descriptive and applied functions. Descriptively, it maps how existing studies measure isolated aspects of DanceSport. Practically, it helps coaches and researchers connect a training or evaluation task to a defined evidence domain. The framework does not imply that one movement template is optimal for every dancer, style, or competitive context.

Classification of SDM

Based on evidence domain and practical function, the working SDM comprises three primary domains and eight sub-models. These categories are heuristic and are intended for future testing rather than presented as an empirically confirmed taxonomy.

Table 1 Working classification of the Sports Dance Model (SDM)

No.	Primary Classification	Secondary Sub-model	Core Function	Application Scenario
1	Technical-movement domain	Basic technique model	Define style-specific posture, footwork, timing, and actions	Technique instruction, foundational training
2		Routine organization model	Describe sequencing, transitions, and musical structure	Routine construction, competition preparation
3	Biomechanical and physical domain	Kinematic-control model	Characterize balance, segmental coordination, and loading	Movement analysis, technical feedback
4		Physical-capacity and load model	Assess physiological demand, conditioning, and injury-related load	Conditioning, workload monitoring, safety
5	Partnered-performance domain	Partner interaction model	Describe physical connection and spatial-temporal coordination	Partnered practice and competition
6		Psychological partnership model	Describe trust, engagement, and instrumental or expressive ties	Partner development, performance support
7		Artistic-presentation model	Organize musicality, interpretation, expression, and presentation	Judging and stage presentation
8		Competition strategy and evaluation model	Connect performance components to rules and decision making	Competition planning and adjudication

The sub-models are analytically distinct but operationally connected. The technical-movement domain specifies what is performed; the biomechanical and physical domain addresses how movement is controlled and sustained; and the partnered-performance domain addresses coordination,

communication, interpretation, and competitive presentation. This organization is consistent with the four WDSF judging components while also incorporating physiological and psychological evidence not captured by a single score [1, 2, 7-20].

Core characteristics of SDM

The reviewed evidence supports six recurring characteristics: technical standardization, biomechanical rationality, partner coordination, combined sporting and artistic attributes, hierarchical organization, and scenario-dependent adaptation. These characteristics are proposed as a synthesis across evidence domains. Their strength and generalizability differ, and those differences are stated below.

Characteristic 1: Style-specific technical standardization

Technical standardization is grounded most directly in WDSF technique books and adjudication criteria [1, 2]. The standards define dance-specific actions, timing, foot positions, posture, holds, and transitions. Standardization therefore refers to agreed technical reference points within each style, not to one identical movement pattern across all DanceSport disciplines.

Basic-action standardization is style-specific. Standard dances emphasize coordinated posture, hold, swing, sway, rotation, and rise-and-fall, whereas Latin dances use different actions and rhythmic organizations [1]. These distinctions should be preserved when constructing training tasks or research variables. Footwork illustrates the need for citation precision. WDSF sources specify foot positions and actions for Standard and Latin styles [1]. The Samba plantar-pressure study provides empirical information about loading in one Latin step pattern [3], but it cannot be

used to support Waltz footwork. Standard-dance claims should instead draw on Standard-specific kinematic and biomechanical evidence [4-10].

Posture and movement execution have been quantified in several Standard-dance studies. Research on Waltz spins, Viennese Waltz turns, sway, contrary body movement, and rise-and-fall shows measurable differences in segmental motion, trajectory, and partner-dependent execution [4-10]. These findings support measurable technical reference points while remaining specific to the movements studied.

Accordingly, SDM combines common performance domains with style-specific implementations. The framework may identify shared questions, such as balance or partner coordination, but the operational indicators must be defined separately for each dance style.

Characteristic 2: Evidence-based biomechanical rationality

Biomechanical rationality concerns whether a proposed movement description is consistent with measured kinematics, loading, balance control, and segmental coordination. Evidence is available for selected Standard and Latin actions, but it does not yet constitute a complete mechanical model of DanceSport [3-10].

Dynamic postural control is supported by studies of Waltz spins, Viennese Waltz turns, and sway. These studies quantify stride

length, trajectories, pelvic and thoracic motion, and angular-velocity profiles, with some variables differentiating performance level or associating with adjudicators' scores [5, 6, 8, 9].

Segmental coordination and force transfer should be described through measured movement variables rather than generalized chains. Waltz studies show that partnering changes lower-limb joint motion, step length, and rise-and-fall patterns [7, 10], while Samba plantar-pressure analysis documents discipline-specific foot loading [3]. Together, these findings support movement-specific mechanical analysis, not a universal sequence of force transmission. Physical capacity and load management form a supporting rather than purely biomechanical component. Simulated Latin competition produces high and dance-dependent cardiovascular and perceived-exertion demands [17]. Anaerobic testing, injury surveys, and the validated Ballroom Aerobic Test further indicate that conditioning and load monitoring should be linked to DanceSport-specific tasks [18-20].

Characteristic 3: Partner coordination

DanceSport performance is produced by a dyad. Partner coordination includes physical interaction, spatial-temporal adaptation, communication, and psychological partnership. This characteristic is supported by both movement studies and partner-relationship research [7, 10-16].

Temporal and musical coordination is explicit in the WDSF Movement to Music and Partnering Skills components [2]. Empirical studies have not yet produced a universal synchrony threshold across styles, so rhythm coordination should be treated as a measurable research target rather than an already quantified SDM rule. Spatial and kinematic coordination is demonstrated most directly in competitive Waltz. Comparing solo and partnered conditions shows that partnership affects joint range, step length, and rise-and-fall motion [7, 10].

These results support partner-dependent movement analysis but should not automatically be extended to open-hold Latin actions. Psychological partnership includes interpersonal perception, instrumental and expressive ties, engagement, personality compatibility, and competition-related emotional regulation [11-16]. Associations with self-reported or rated performance support their inclusion, although causal direction and cross-cultural transportability remain open questions.

Characteristic 4: Combined sporting and artistic attributes

DanceSport combines competitive regulation with artistic presentation. This duality is explicit in the WDSF system: Technical Quality and Movement to Music emphasize technical execution, while Partnering Skills and Choreography and

Presentation capture interpersonal and expressive dimensions [2].

The sporting dimension includes rule-governed competition, technical assessment, physical demand, and performance comparison. Kinematic variables associated with adjudication scores and partnership variables associated with competitive performance illustrate measurable parts of this dimension [8, 9, 13, 14].

The artistic dimension includes musical interpretation, choreography, expression, and presentation [2]. The current peer-reviewed evidence base is less developed for these constructs than for selected kinematic variables. The framework therefore treats artistic presentation as an essential domain whose measurement requires further validation.

The two dimensions should not be collapsed. Technical compliance provides constraints, while artistic interpretation differentiates how technically acceptable material is presented. Their balance varies by round, judging system, and performance context.

Characteristic 5: Obvious hierarchical structure

SDM is presented as a three-layer working hierarchy: a core layer, a support layer, and a presentation layer. The hierarchy is a conceptual ordering of training and evaluation questions, not evidence that learning must always proceed in a fixed sequence.

Table 2 Working hierarchical structure of SDM

Hierarchy	Included Sub-models	Core Position	Main Function
Core Layer	Basic technique model; kinematic-control model	Style-specific technical core	Define reference actions and measurable movement control
Support Layer	Physical-capacity and load model; psychological partnership model	Intermediate support structure	Support repeatable performance, health, engagement, and cooperation
Presentation Layer	Routine organization; partner interaction; artistic presentation; competition strategy and evaluation	Observable performance layer	Integrate technical, interpersonal, musical, and competitive outputs

The core layer contains style-specific technique and kinematic control. The support layer contains physical capacity, load

management, and psychological partnership. The resentation layer contains routine organization, partner interaction, musical-

artistic presentation, and competition strategy or evaluation. This hierarchy helps identify dependencies without implying determinism. For example, physical fatigue may reduce technical consistency, and partnership quality may influence engagement and performance [13, 14, 17-20]. However, the relative importance of each layer may differ across styles, competitive levels, and individuals.

Characteristic 6: Scenario-dependent adaptation

The framework should adapt to the purpose of use while retaining explicit evidence boundaries. Training, competition, and stage performance emphasize different outputs, and each requires indicators appropriate to the relevant dance style and population.

In training, tasks may isolate technique, kinematics, physical capacity, or partner interaction. Standard-dance sensor studies provide examples of movement-specific feedback [4-10], while physiological and injury studies support conditioning and load-monitoring objectives [17-20].

In competition, the framework should align with the governing judging system. Technical Quality, Movement to Music, Partnering Skills, and Choreography and Presentation provide the most defensible top-level categories [2]. Biomechanical or psychological measurements can inform preparation, but they should not be

presented as replacements for validated adjudication procedures.

In stage-oriented performance, choreographic and expressive freedom may receive greater emphasis. Even so, claims about artistic quality should remain linked to explicit criteria rather than assumed to follow automatically from technical execution [1, 2]. Scenario adaptation therefore means changing priorities and indicators, not abandoning discipline-specific technique or evidence standards.

Coupling relationships among core characteristics

The six characteristics form a proposed dependency network rather than six independent traits. Technical standards define reference actions; biomechanical evidence tests selected aspects of their execution; physical and psychological support influences repeatability; partner coordination shapes dyadic performance; and the judging context determines which outputs are evaluated [1, 2, 7-20]. The network is plausible and practically useful, but its pathways and weights require empirical testing.

Evidence distribution and boundary conditions

The evidence base is uneven across DanceSport disciplines. Standard-dance studies, particularly Waltz and Viennese Waltz, dominate the kinematic literature [4-10]. Latin evidence in the present set

concerns Samba plantar pressure and competition physiology [3, 17]. The framework should therefore avoid using a Latin study to validate a Standard technique, or vice versa, unless a direct comparative study supports the transfer.

The partner-psychology literature is recent and informative, but several studies use Chinese athlete samples and self-report or rated-performance measures [11-16]. These results justify partnership constructs within SDM while leaving cultural invariance and causal mechanisms unresolved. Technology studies show that automated dance recognition and quality evaluation are technically feasible [21, 22]. However, they do not yet validate an SDM scoring system for competitive ballroom dance. Future systems must use DanceSport-specific datasets, style-specific labels, independent adjudicators, and transparent reliability and validity tests.

4. CONCLUSIONS

This structured conceptual review supports the following conclusions:

First, SDM is best understood as a provisional evidence-organizing framework. The proposed three-domain, eight-sub-model classification links style-specific technique, movement mechanics, physical capacity, partner interaction, psychological partnership, artistic presentation, and competition-related decision making.

Second, six recurring characteristics can

be identified: technical standardization, biomechanical rationality, partner coordination, combined sporting and artistic attributes, hierarchical organization, and scenario-dependent adaptation. The characteristics are supported unevenly; they should not be treated as equally validated dimensions.

Third, the strongest empirical support concerns selected Standard-dance biomechanics and DanceSport partnership constructs. The evidence is more limited for Latin-specific mechanics, cross-style comparisons, artistic-expression measurement, cross-cultural generalization, and automated DanceSport quality assessment.

Fourth, the practical value of SDM lies in making training and evaluation assumptions explicit. It can help practitioners connect a task to a technical, biomechanical, physical, interpersonal, or artistic target and identify whether the supporting evidence is direct or indirect.

This review has limitations. It includes English-language sources only, combines heterogeneous study designs, and uses narrative conceptual synthesis rather than meta-analysis. Most kinematic studies involve small samples and selected Waltz or Viennese Waltz actions, while much of the recent partnership evidence comes from Chinese athletes. No validated instrument currently measures the complete SDM framework.

Future work should preregister style-specific hypotheses, recruit larger and more diverse samples, compare Standard and Latin disciplines directly, and test whether proposed indicators predict independent performance outcomes. A quantitative SDM instrument should be developed only after content validity, reliability, measurement invariance, and criterion validity have been established.

Technology-assisted research is promising but should proceed cautiously. Computer vision and spatiotemporal models can recognize and evaluate dance movement [21, 22], yet DanceSport-specific datasets, transparent scoring targets, cross-view validation, and agreement with qualified adjudicators are required before such systems can support high-stakes training or judging.

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Evaluation of the Antibacterial Potential of *Eichhornia crassipes* Leaf Extract Against *Aeromonas hydrophila* and *Streptococcus agalactiae* for Potential Application in Aquaculture

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ABSTRACT

The excessive use of antibiotics in aquaculture has raised concerns regarding antimicrobial resistance and drug residues, creating a need for natural antibacterial agents. This study evaluated the antibacterial activity of a 70% ethanolic leaf extract of *Eichhornia crassipes* against *Aeromonas hydrophila* and *Streptococcus agalactiae*. Phenolic compounds were characterized by HPLC, while antibacterial activity was evaluated using agar well diffusion, minimum inhibitory concentration (MIC), and minimum bactericidal concentration (MBC) assays. The extraction yield was 14.07%, and the major phenolic compounds identified were quercetin (0.22 ± 0.00 mg/g extract), protocatechuic acid (0.17 ± 0.02 mg/g extract), and gallic acid (0.06 ± 0.00 mg/g extract). The extract exhibited concentration-dependent antibacterial activity, producing inhibition zones of 11.70 ± 0.03 mm against *A. hydrophila* and 10.70 ± 0.06 mm against *S. agalactiae* at 750 mg/mL. The MIC/MBC values were 50/100 mg/mL for *A. hydrophila* and 100/400 mg/mL for *S. agalactiae*, indicating greater susceptibility of *A. hydrophila*. Although less active than commercial antibiotics, the extract demonstrated moderate antibacterial activity and may serve as a potential natural antibacterial agent for sustainable aquaculture.

Keywords: *Eichhornia crassipes*, antibacterial activity, *Aeromonas hydrophila*, *Streptococcus agalactiae*, aquaculture.

1. INTRODUCTION

Disease outbreaks caused by bacterial pathogens continue to threaten freshwater aquaculture, leading to reduced productivity, increased mortality, and considerable economic losses. Among these pathogens, *Aeromonas hydrophila* and *Streptococcus agalactiae* are frequently associated with disease outbreaks in *Nile tilapia* culture [1]. Although antibiotics remain the primary treatment, their widespread use has contributed to antimicrobial resistance, drug

residues, and environmental concerns, creating a need for safer natural alternatives [2]. *E. crassipes* (water hyacinth) is recognized as one of the world's most aggressive invasive aquatic plants. Its rapid proliferation blocks sunlight penetration, reduces dissolved oxygen levels, disrupts aquatic ecosystems, and negatively affects fisheries and agricultural productivity [12]. Therefore, utilizing this invasive biomass as a source of bioactive compounds represents a sustainable strategy for both environmental

management and value-added applications. Previous studies have demonstrated that *E. crassipes* leaf extracts exhibit antibacterial activity against several human-associated bacteria [3-5]. In addition, phytochemical investigations have identified various phenolic acids and flavonoids, including gallic acid, protocatechuic acid, and quercetin, which are associated with antimicrobial and antioxidant activities [6-8]. However, information regarding the antibacterial activity of *E. crassipes* against economically important fish pathogens remains limited. Moreover, host-pathogen interactions in fish are highly species-specific, making antibacterial efficacy difficult to extrapolate across different pathogenic species [13].

Therefore, this study evaluated the antibacterial potential of a 70% ethanolic leaf extract of *E. crassipes* against *A. hydrophila* and *S. agalactiae*. The extract was characterized by HPLC, and its antibacterial activity was evaluated using agar well diffusion, MIC, and MBC assays. The findings provide new information on the antibacterial potential of *E. crassipes* leaf extract and support its future development as a natural antibacterial candidate for sustainable aquaculture applications.

2. MATERIALS AND METHODS

2.1 Preparation of Leaf Extract

Fresh *E. crassipes* leaves were washed thoroughly with tap water and dried under natural sunlight in a clean, well-

ventilated area for approximately 24 h until constant weight. The dried leaves were stored in an airtight container containing a desiccant until extraction.

The dried leaf material was extracted with 70% (v/v) ethanol (1:30, w/v) by maceration at room temperature for 5 days [9]. The extract was filtered through muslin cloth, concentrated under reduced pressure using a rotary evaporator (50–60°C), and stored under refrigeration until analysis.

2.2 HPLC Analysis

The phytochemical profile of the *E. crassipes* leaf extract was analyzed using a HPLC-PDA system (Nexera LC-40DXR-PDA/ELSD, Shimadzu, Japan) with a Gemini C18 column (250 × 4.6 mm, 5 μm). The mobile phase consisted of 0.1% formic acid in water (A) and acetonitrile (B). The column temperature was maintained at 35°C, the injection volume was 20 μL, and detection was performed at 280 nm. Phenolic compounds were identified by comparison with authentic standards and quantified using external calibration curves.

2.3 Preparation of Bacterial Inoculum and Agar Well Diffusion Assay

A. hydrophila (24803) and *S. agalactiae* (ST-CU65) were cultured on TSA and subsequently grown in TSB to the logarithmic phase ($OD_{600} \approx 0.6$). Cells were washed with PBS (pH 7.4) and adjusted to approximately 1.0×10^9 CFU/mL.

The antibacterial activity of the *E. crassipes* leaf extract was evaluated using the agar well diffusion method with

modifications in the concentrations of the test extract and positive controls. Bacterial suspensions were spread onto TSA plates, and 6-mm wells were filled with 50 μ L of extract at concentrations of 62.5, 125, 250, 500, and 750 mg/mL. Oxytetracycline (2 mg/mL) and ENRO PLUS-A (enrofloxacin/norfloxacin, 2 mg/mL) were used as positive controls, while sterile distilled water served as the negative control. After incubation at 37°C for 18 h, inhibition zone diameters were measured. All experiments were performed in triplicate.

2.4 Determination of Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC)

MIC and MBC of the *Eichhornia crassipes* leaf extract were determined using the broth microdilution method in sterile 96-well microplates. Two-fold serial dilutions of the extract were prepared from an initial concentration of 800 mg/mL, resulting in final concentrations ranging from 400 to 0.20 mg/mL. Bacterial suspensions were adjusted to a final inoculum of 5×10^5 CFU/mL in each well, with a total reaction volume of 200 μ L. Growth and sterility controls were included in each assay. After incubation at 37°C for 18 h, the MIC was defined as the lowest concentration showing no visible bacterial growth. For MBC determination, 10 μ L aliquots from wells showing no visible growth were spread onto TSA plates and incubated at 37°C for 18 h. The MBC was defined as the lowest concentration at which no bacterial colonies were observed.

3. RESULTS AND DISCUSSION

3.1 Extraction Yield and HPLC Analysis

The extraction yield of 14.07% (w/w) indicates that 70% ethanol was able to recover a measurable amount of polar and moderately polar phytochemicals from *E. crassipes* leaves. HPLC analysis identified three phenolic compounds in the leaf extract, namely gallic acid, protocatechuic acid, and quercetin (Table 1).

Table 1. Phenolic compounds identified in the *Eichhornia crassipes* leaf extract by HPLC.

Phenolic compound	Content (mg/g extract)
Gallic acid	0.06 $\pm$ 0.00
Protocatechuic acid	0.17 $\pm$ 0.02
Quercetin	0.22 $\pm$ 0.00

Among the identified compounds, quercetin was the predominant constituent, followed by protocatechuic acid and gallic acid. Similar phenolic compounds have previously been reported in *E. crassipes* and are associated with antibacterial and antioxidant activities [6-8]. Similar phenolic profiles and biological activities of *E. crassipes* extracts have also been reported following extraction optimization, highlighting the potential of this plant as a source of bioactive compounds [10]. The presence of these compounds is likely associated with the antibacterial activity observed against *A. hydrophila* and *S. agalactiae* [6-8]. However, because the extract was evaluated as a crude extract containing multiple bioactive constituents, the contribution of each compound could not be determined.

3.2 Antibacterial Activity of *Eichhornia crassipes* Leaf Extract

The antibacterial activity of the *E. crassipes* leaf extract against *Aeromonas hydrophila* and *Streptococcus agalactiae* was evaluated using the agar well diffusion method. Representative inhibition zones are shown in Figure 1, while the corresponding inhibition zone diameters are summarized in Table 2.

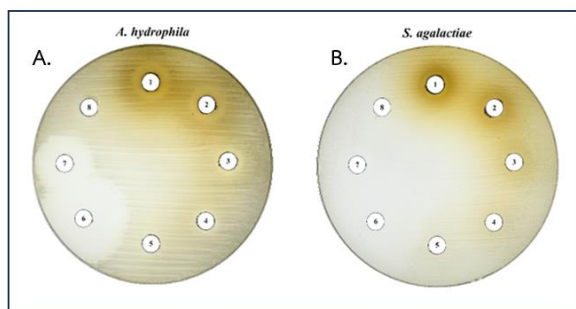


Figure 1. Antibacterial activity of *Eichhornia crassipes* leaf extract against *Aeromonas hydrophila* (A) and *Streptococcus agalactiae* (B) determined by the agar well diffusion assay.

Growth inhibition increased with extract concentration in both bacterial species [11] (Table 2). For *A. hydrophila*, inhibition zones were observed at extract concentrations ranging from 125 to 750

mg/mL, whereas inhibition against *S. agalactiae* was detected only at concentrations of 250 mg/mL and above. At 750 mg/mL, the extract produced the largest inhibition zones for both *A. hydrophila* and *S. agalactiae*. No inhibition was observed at 62.5 mg/mL for either bacterium.

Both positive controls exhibited greater antibacterial activity than the plant extract. ENRO PLUS-A produced the largest inhibition zones against both bacterial strains, followed by oxytetracycline. No inhibition zone was observed in the negative control, confirming that the solvent did not exhibit antibacterial activity. The higher antibacterial activity observed against *A. hydrophila* may be associated with the combined effects of phenolic compounds identified in the extract, particularly quercetin, protocatechuic acid, and gallic acid [6-8]. Similar antibacterial activity of *E. crassipes* leaf extracts against various bacterial species have previously been reported [11], supporting the antibacterial potential observed in the present study.

Table 2. Inhibition zone diameters of *Eichhornia crassipes* leaf extract against *Aeromonas hydrophila* and *Streptococcus agalactiae* determined by the agar well diffusion assay.^a

Sample	Concentration (mg/mL)	<i>A. hydrophila</i> (mm)	<i>S. agalactiae</i> (mm)
<i>E. crassipes</i> leaf extract	750	11.70 ± 0.03	10.70 ± 0.06
	500	10.70 ± 0.06	9.30 ± 0.06
	250	8.80 ± 0.03	6.00 ± 0.00
	125	6.50 ± 0.05	–
	62.5	–	–
ENRO PLUS-A (positive control)	2	30.3 ± 0.06	31.5 ± 0.05
Oxytetracycline (positive control)	2	18.5 ± 0.00	11.0 ± 0.00
Sterile distilled water (negative control)	–	–	–

^a Note: Data are presented as the mean $\pm$ standard deviation (SD) of three independent experiments. The symbol (–) indicates no inhibition zone

3.3 Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC)

The MIC and MBC values of the *Eichhornia crassipes* leaf extract and the positive controls are summarized in Table 3. The extract exhibited stronger antibacterial activity against *A. hydrophila* than against *S. agalactiae*. The MIC and MBC values against *A. hydrophila* were 50 and 100 mg/mL, respectively, whereas those against *S. agalactiae* were 100 and 400 mg/mL, respectively. These findings were consistent with the agar well diffusion assay, in which larger inhibition zones were

observed for *A. hydrophila* than for *S. agalactiae*. In contrast, ENRO PLUS-A showed the highest antibacterial activity against both bacterial strains, while oxytetracycline was less effective against *S. agalactiae* than against *A. hydrophila*. The antibacterial effects observed may be attributed to the phenolic constituents detected by HPLC, particularly quercetin, protocatechuic acid, and gallic acid. These phytochemicals are known to suppress bacterial growth through multiple mechanisms, including disruption of membrane integrity and interference with essential cellular functions [6-7].

Table 3. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of *Eichhornia crassipes* leaf extract and positive controls against *Aeromonas hydrophila* and *Streptococcus agalactiae*.

Treatment	Unit	<i>A. hydrophila</i> MIC	<i>A. hydrophila</i> MBC	<i>S. agalactiae</i> MIC	<i>S. agalactiae</i> MBC
<i>E. crassipes</i> leaf extract	mg/mL	50	100	100	400
ENRO PLUS-A	µg/mL	<0.98	<0.98	<0.98	<0.98
Oxytetracycline	µg/mL	7.81	7.81	500	>2,000

Note: ">2,000" indicates that the MBC exceeded the highest concentration tested (2,000 µg/mL).

Similar antibacterial effects of *E. crassipes* leaf extracts have also been reported against several pathogenic bacteria, including *S. epidermidis*, *P. acnes*, and *P. intermedia* [3-5, 11]. The greater susceptibility of *A. hydrophila* observed in the present study suggests that *E. crassipes* leaf extract may have potential as a natural antibacterial agent for controlling bacterial diseases in aquaculture. Considering that

both *A. hydrophila* and *S. agalactiae* are major bacterial pathogens in *Nile tilapia* culture, the present findings support the potential application of *E. crassipes* leaf extract as a natural antibacterial ingredient for the development of feed coatings or other sustainable disease management strategies in aquaculture [2,13]. This difference may reflect species-specific susceptibility to phenolic compounds and

differences in bacterial physiology, although the precise mechanism requires further investigation.

4. CONCLUSIONS

The present study demonstrated that a 70% ethanolic leaf extract of *E. crassipes* possesses moderate antibacterial activity against two important fish pathogens, *A. hydrophila* and *S. agalactiae*. HPLC analysis revealed quercetin, protocatechuic acid, and gallic acid as the predominant phenolic constituents, which are likely associated with the observed antibacterial activity. The extract showed greater efficacy against *A. hydrophila* than *S. agalactiae*, although its activity remained lower than that of the commercial antibiotics. These findings support the potential utilization of *E. crassipes* as a sustainable source of natural antibacterial compounds for aquaculture. Further studies should focus on evaluating its safety, stability, and in vivo performance before practical application.

5. ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Faculty of Science and Technology, Phranakhon Rajabhat University, Thailand, for supporting this research.

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Electronic word-of-mouth in dental tourism: A netnographic analysis of public online communities

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ABSTRACT

Prior to choosing any specific clinic, numerous individuals thinking about dental care abroad tend to read different publicly available online discussions so that they could understand how other patients were being cared for. This research was dedicated to understanding how these discussions were used by individuals in planning dental treatment in Thailand. The dataset included about 60 posts and comments that came from 11 general English-speaking threads found in Reddit and ASEAN Now. The collected data consists of discussions published during the years 2021-2026 and relate to the matters of both simple and complicated types of dental care. The usernames and other identifiable information were eliminated from the sample prior to conducting analysis. The extracted paraphrased content has been used instead of quotes in order to make tracking down the specific posts through online search less possible.

Coding was initiated with the problems regarding which the posters raised concerns in the discourse. Then the principles were interpreted according to Information Adoption Model, Uses and Gratifications Theory, and Theory of Planned Behavior. Five themes were defined: credibility formed by shared experience, correlation of price and transparency, risk management through warnings and second opinions, suitability of treatment with respect to journeys, and transition from information search to choice of service provider or destination. Price was not the sole factor under consideration of the posters and recommendation of the clinic by itself was seldom sufficient. Posters tended to listen more carefully if the story involved description of the course of the treatment, mention of the performer of the intervention, details about follow up arrangement, or the effectiveness of the treatment in a long run.

Keywords: dental tourism, digital word-of-mouth, netnography, public online communities

1. INTRODUCTION

For a considerable number of patients, going for a dental procedure abroad is not merely a matter of spending money on tourism. The decision could relate to the matter of restorative treatment, denture making, beauty operations, or another type

of prosthetic work. The outcome can have a lasting effect and go far beyond the duration of a trip. Bangkok is to be distinguished among other places for its private medical service and dental specialists, as well as tourism industry and affordable pricing situation concerning the treatment [1-7]. However, the fact that the quoted price for

services seems to be low does not imply that there will be no worries after the treatment about receiving necessary clinical services, being subject to some complications, getting post-operation treatment, and other procedures once back home.

Websites of clinics provide knowledge on dental procedures and costs, but they fail to address everything encountered in reality. Were there any painful moments in the course of treatment? Did the payment amount remain unchanged? Was the dental staff available for all options of treatment discussed? Did you have to come back to the clinic several times? Hence, it is understandable that the patients might address such questions in social media, receiving real-life responses in return. The conversations and opinions of posters constitute eWOM in terms of e-marketing [8-11].

This study combines three different aspects that consider all significant components of decision-making. The Information Adoption Model (IAM) focuses on the issue of trust in the message which involves its credibility and ability to influence people positively [12]. The Uses and Gratifications Theory (UGT) explains the reason for people coming to these platforms, indicating that they may be searching for information, comfort, or social support [13]. The Theory of Planned Behavior (TPB) deals with the notion of people's attitudes as well

as the influence of other people on one's decisions when they believe that the therapy is something feasible [14]. Using these three perspectives together makes it possible to evaluate the information that people exchange online and how it affects decision-making.

Electronic word of mouth (eWOM) has gained momentum in business research, especially in the field of tourism. Nonetheless, there are still gaps in our understanding of the discussions related to credibility and value, risk communication, and travel arrangements in the context of dental services in Thailand. Hence, this research made two significant contributions: the first was to identify the main applications of eWOM, and the second was to analyze the impact made by online communication on the posters' evaluations of dental establishments, understanding of risks, and willingness to seek treatments.

2. MATERIALS AND METHODS

2.1 Research design

This study employed a qualitative netnographic methodology to investigate the spontaneous discussions on the internet [15,16]. During the data gathering process, the researchers did not take part in the on-line discussions nor communicate directly with the posters. Reflexive thematic analysis was chosen for the study since it deals with the meaning attributed by the posters to the

information concerning the oral health care professionals, the cost of treatments, possible threats and travel arrangements instead of measuring fixed variables [17,18].

2.2 Scoping search, selection, and final sample

The process of scoping took place from March to April 2026. During this phase, the search utilized combinations of either “Thailand” or “Bangkok” and words online concerning “dental tourism”, “dental implant”, “veneers,” “crown,” “dentist,” and “dental work.” This initial result produced 30 threads on Reddit, Tripadvisor, and ASEAN NOW.

To qualify for inclusion into the sample, a discussion had to be found to be written in English and be of free access. In

Tripadvisor was ultimately excluded from the final analysis because complete threads could not be accessed throughout the study. Facebook data was ignored for another reason: posts could not be proved to be publicly available without joining an appropriate group or logging into a profile. After the screening procedure, the pool shrank to just 11 threads: 5 from Reddit and 6 from ASEAN NOW. Posts and comments were checked manually: 30 Facebook and 30 Reddit entries. The selected materials were dated between 2021 and 2026, thereby covering regular and more complex dental procedures.

Table 1. Final empirical sample

Platform	Threads	Discussion extracts	Date range	Dominant discussion types
Reddit	5	30	2023-2026	Immediate experiences, short recommendations, and travel-planning questions
ASEAN NOW	6	30	2021-2025	Technical comparisons, cost detail, and long-term treatment experiences
Total	11	60	2021-2026	Implants, veneers, crowns, bridges, dentures, cleaning, and related procedures

Source: Adopted from this study

kept if the posters provided useful information about their experience of treatment, costs of with another destination. Conversations were dental procedures, risks related to treatment, dental work in Thailand

or compare Thailand travel organization, or choice of a dental provider.

2.3 Data Collection and Analysis

All of selected posts and comments were considered as an individual discussion record. For each of the records mentioned above we wrote down the platform, the

thread, the approximate date, the treatment discussed, the step of the decision-making process, eWOM data and the theoretical codes. The names, details of profile, pictures, phone numbers and other types of contact information were excluded from the dataset. Ultimately, since the direct quotations from public forums may be easy to trace down through the search engine, the paper is going to use the verbal analytic paraphrases with reference to the anonymous identifiers (U001-U060). The URLs related to the sources of information and the coding notes constitute a separate set in a secured form.

2.4 Coding and thematic analysis

Before formal coding began, all threads were read several times to gain familiarity with the material. Initial notes focused on the questions raised by posters, the kinds of evidence they found convincing, and points in the discussions that appeared to influence treatment decisions. Coding combined concepts drawn from the theoretical framework, including source credibility, argument quality, subjective norms, and perceived behavioral control, with additional codes developed directly from the data [17,18]. The codes were then compared across threads, revised where necessary, and grouped into five main themes.

Although some extracts received more than one code, Table 2 reports the

primary theme assigned to each extract. The counts describe how the themes were distributed across the corpus and were not treated as statistical measures. A codebook and an audit trail linking the coded extracts to their original sources were maintained throughout the analysis. Patterns were compared across Reddit and ASEAN NOW, with attention also given to extracts that differed from or challenged the developing interpretations. No substantially new themes appeared in the final ten extracts. This was taken as a practical indication that the corpus was adequate for the exploratory purpose of the study, rather than as definitive evidence of thematic saturation.

The lead author completed the initial coding and theme development. A coauthor then reviewed a purposively selected subset representing both platforms and all five themes, including extracts that had received multiple codes or required closer interpretation. Differences in coding and interpretation were discussed, and the agreed revisions were recorded before the themes were finalized.

2.5 Ethical considerations

The ethical framework used is similar to that of the Association of Internet Researchers [19]. Only publicly available information was used that did not require consent from any group members. Although the topic of health-related information can still be considered sensitive, it is important to

keep in mind that no revealing information was included in this study.

3. RESULTS AND DISCUSSION

3.1 Overview of the thematic structure

The posters in the 11 threads expressed their views with a mixture of both good and bad experiences. Positive reviews were shared along with complaints about some issues that remained unresolved or requests of help. Practical advice was given

on the threads as well as individuals telling their own stories. The data revealed five types of themes. There are Socially constructed credibility, Conditional value and price transparency, Risk negotiation and second opinions, Travel-time feasibility and continuity and Intention formation and destination choice. The most common type of codes assigned to the threads was credibility. Table 2 shows the primary code for all the 60 extracts although there may be some secondary codes linked to them.

Table 2. Themes identified in 60 discussion extracts

Theme	n	%	What the theme captured	Theory link
Socially constructed credibility	20	33.3%	Trust emerged through detail, expertise, long-term outcomes, referrals, and challenges to promotional claims.	IAM
Conditional value and price transparency	14	23.3%	Low price attracted attention, but transparent quotations, materials, competence, and absence of upselling defined value.	IAM; UGT; TPB
Risk negotiation and second opinions	11	18.3%	Warnings, negative cases, second opinions, and aftercare narratives were used to manage uncertainty.	UGT; TPB
Travel-time feasibility and continuity	8	13.3%	Appointment timing, length of stay, healing periods, and repeat visits shaped perceived feasibility.	TPB
Intention formation and destination choice	7	11.7%	Discussion supported provider shortlisting, return intention, alternative selection, and destination switching.	IAM; TPB

3.2 Credibility built through experience and communication

Posters usually do not trust recommendations of clinics without supporting information. It was not enough to just provide a clinic name unless the detail of treatment, doctor, treatment procedure,

and result were provided. Analysis of the data showed that 20 fragments were coded with the credibility theme. For instance, one person stated that an implant that had been put in place about a year ago did not create any problems, which made the treatment seem credible (U019). Another person says

that the implants he has received are still working well after they were introduced in 2010 (U058).

Moreover, the credibility of comments that appeared sponsored or promotional was also scrutinized. Such comments were not automatically considered credible, particularly when they provided little information about the treatment process (U027, U054, U059–U060). Posters evaluated these opinions against their own experiences and occasionally challenged them. Thus, although the two forms of evaluation proposed by the IAM are closely related, distinguishing between them remains analytically useful.

3.3 Price mattered, but value depended on transparency

Price played an important role in conversations on dental proceedings; however, value perception was based on transparency. This view was supported by fourteen quotations classified mainly in regard to the value and price transparency topic. Comparing the costs of procedures conducted in Australia and the USA indicated that dental treatment in Thailand may be appealing from a financial viewpoint. However, posters had a strong distinction between low-priced services and services with good value. For example, dental cleaning was considered rather expensive, Although, it was positively evaluated if the

procedure took place in a quick and appropriate manner (U006). The same situation happens regarding implants since posters are ready to pay more for it if they are sure about the skillfulness of the dentist and the technology (U018, and U034).

Perceptions of value were greatly affected by transparency of the information. Posters made it clear that they prefer clinics where it is easy to find out the costs of procedures. Itemized estimates, conversations about materials, and schedule of procedures were highly valued (U009, U025, U046, U056). On the other hand, price increases without any explanation and suggested procedures that are considered unnecessary disappointed clients and created dissatisfaction (U021-U022).

3.4 Risk management through warnings and second opinions

Risk management was explored based on various treatment experiences instead of cases where the term is used in general. In the 11 extracts selected, certain painful or complicated interventions, high costs, as well as issues such as over-treatment and the dentist's qualifications were discussed (U002, U020 – U022, U026). The comments also pointed out specific issues that the patient should pay attention to before starting treatment, such as whether there was a written treatment plan developed by the clinic and whether this

treatment was actually required. The negative experiences helped the members of the community to gain some insights in the evaluation of the dentists and the clinics.

One of the most evident ways in which posters managed uncertainty was by seeking a second opinion. Two cases showed that a second opinion influenced the eventual treatment decision. In one case, a poster reported receiving a crown instead of the initially proposed implant. In another, a poster avoided tooth extraction after being advised that root canal treatment was still possible (U038, U043). Posters also raised questions about health assessments before treatment, as well as recovery time and follow-up care after returning home (U005, U024, U040).

3.5 Integration of treatment with travel and follow-up

Treatment schedules did not always align with posters' travel plans. Eight extracts raised practical concerns about whether dental treatment could be completed within the time available during a visit to Thailand. One poster planned to stay for 10–14 days but had not yet decided whether to arrange the dental appointment or book the flight first (U013–U014). Responses indicated that implant treatment generally required a healing period of several months before the crown could be placed. Consequently, returning to Thailand for a second visit was often presented as a practical requirement

rather than a matter of personal preference (U015–U016, U040–U042).

Travel considerations influenced posters' decisions about which clinic to choose. Posters considered the distance between clinics and their accommodation, the accessibility of clinics by public transport, and the possibility of securing an appointment within a short period (U008–U009). Although these factors did not directly reflect clinical quality, they influenced whether posters perceived the proposed treatment as practically feasible.

3.6 From online discussion to provider and destination choice

The outcome of the discussions did not always result in making a choice, although seven excerpts depict the shift from the search for information to the use of that information. Some posters shared their previous positive experiences with dental treatments as an indication of plans to engage in further treatment, like bridges, crowns, or implants (U004, U010, U019, U058). In a separate thread, the frequent references to a certain provider made a poster think about engaging their services (U045). In another case, a dental service offered by a university was proposed as a less expensive option (U057). The case of Turkey (U049) presents particular significance as the posters eventually chose to go with treatment in a different country versus getting the same therapy in Thailand. All the

above cases indicate the influence of various factors on the final decision.

4. DISCUSSION

4.1 Interpreting the findings through IAM, UGT, and TPB

The findings support the central argument of the Information Adoption Model that source credibility and argument quality influence whether online information is considered useful and worth adopting [12]. This interpretation is also consistent with previous eWOM research, which has shown that consumers are more likely to use online information when it appears credible, relevant, and sufficiently detailed [9,10]. In the present study, however, credibility did not depend only on the qualifications or claimed experience of an individual contributor. Posters also considered how clearly the treatment was described, whether the account included a sequence of events, whether longer-term outcomes were reported, and how other community members responded. Credibility was therefore developed within the discussion itself. Questions, comparisons, and supporting accounts could strengthen a recommendation, whereas missing details or challenges from other posters could weaken it. The findings extend the IAM by showing that, within online communities, source credibility and argument quality may be assessed collectively rather than by each reader in isolation.

The results can also be interpreted through Uses and Gratifications Theory, which

views individuals as active posters of media who seek information and other forms of personal or social benefit [13]. Previous research on eWOM has similarly suggested that people participate in online discussions to exchange experiences, assist others, and express satisfaction or dissatisfaction [8]. The discussions examined in this study served an informational purpose, as posters asked about clinics, treatment costs, materials, and procedures. Yet their participation often continued after these factual questions had been addressed. When posters discussed pain, complications, lingering sensitivity, sales pressure, or the need for another opinion, the threads also became a place for working through uncertainty and seeking reassurance. This finding suggests that informational and emotional needs were closely connected. In the context of dental tourism, posters were not simply gathering facts; they were also comparing their concerns with the experiences of people who had already undergone treatment.

The Theory of Planned Behavior provides a useful explanation of how these discussions moved from information seeking towards possible action [14]. Positive and negative treatment accounts contributed to attitudes towards dental care in Thailand, while recommendations from other posters and referrals from dental professionals contributed to subjective norms. Perceived behavioral control was evident in discussions about treatment costs, appointment availability, healing periods, return visits, and

access to aftercare. These practical concerns are consistent with earlier medical-tourism research showing that affordability may encourage treatment abroad, but concerns about continuity of care, complications, and cross-border follow-up remain important [3,7,20]. The present findings further show that a favorable attitude towards Thai dental care did not necessarily lead to an intention to proceed. A poster might view a provider positively but still consider the required travel schedule or follow-up arrangements unmanageable. This reflects the TPB proposition that behavioral intention may be weakened when individuals perceive limited control over the practical requirements of an action.

The case in which a poster chose Turkey rather than Thailand illustrates how these theoretical elements may operate together (U049). The poster remained interested in receiving dental treatment abroad, but the comparison of cost and treatment time changed the preferred destination. The case suggests that eWOM may influence more than the choice of a clinic. It can also lead prospective patients to reconsider the destination itself when another country appears to offer a more manageable combination of price, treatment duration, and travel requirements. Taken together, the findings show that online discussions influenced dental-tourism decisions through the combined assessment of information credibility, emotional

reassurance, social influence, and practical feasibility.

4.2 Practical implications

Price is often the first point used to attract international patients. In the discussions examined, however, posters rarely considered price on its own. They wanted to know whether the quoted amount was likely to change and who would actually carry out the procedure. Questions were also raised about the materials used, available treatment alternatives, and the time needed to complete each stage. These details became particularly important when treatment involved a healing period or required another trip to Thailand.

Several threads returned to the question of what would happen once the patient was back home. Posters asked who would take responsibility for complications, how later care would be arranged, and whether a clinic would continue to support a patient who sought another opinion. Cost remained important, but these concerns show that affordability was only one part of the decision. Information about clinical standards, professional responsibility, treatment continuity, and aftercare should therefore be presented as clearly as information about price.

Negative posts were also informative. Some posters found the information difficult

to follow or discovered that the final bill was different from the original estimate. Others felt that the treatment outcome fell short of what they had expected. Negative posts were also informative. Some posters found the information difficult to follow or discovered that the final bill was different from the original estimate. Others felt that the treatment outcome fell short of what they had expected. These comments can help clinics see where communication or service has gone wrong. A reply that deals with the actual complaint and sets out the next steps may carry more weight than a general promotional statement.

4.3 Limitations and Future Research

In this study, a total of 60 posts and comments were studied from 11 threads in English language. Although the material used does provide insights into these discussions, they do not represent all the experiences of the dental tourists. Those who participated in the online discussion forums did so voluntarily and are therefore more likely to do so when they experienced something very favorable, disappointing or memorable. Furthermore, the analysis was restricted to certain data since only those posts and comments which could be accessed without being a member of a group were analyzed. Discussions conducted in languages other than English, private Facebook groups, as well as Tripadvisor posts which could not be

accessed on a regular basis were left out of the analysis.

Future research could include discussions in other languages and compare Thailand with other dental-tourism destinations. Following online discussions over time may help show how an initial enquiry develops into a treatment decision and subsequent follow-up care. Interviews with dental tourists could also provide insight into concerns or experiences that individuals may prefer not to discuss publicly.

5. CONCLUSION

The public online communities explored in this research revealed more than just advising clinics. The discussions among prospective patients included comparing how credible the personal stories were, analyzing why prices seemed abnormally low, voicing fears of undesirable treatment outcome, and noting the implications of going to receive dental assistance overseas. The choice of prospective patients turned out to be dependent on such factors as the amount of details available in each gut feeling, proof of the treatment efficiency, clarity of treatment costs, option for a second opinion, and ease of returning for follow-up treatment.

The IAM, UGT, and TPB also provide different explanations for these findings. The IAM explains how posters evaluated the reliability and usefulness of the information.

UGT refers to the posters' objectives of acquiring information, assurance and support. Finally, TPB is used to show how posters' attitudes, their social surroundings, and the limitations affect their intentions. When all these factors are combined, they show that eWOM is relevant during all stages of the dental tourism process: searching for information, finding healthcare performers, and making a final choice. Thus, clinics and destination marketers should not forget to present affordability along with the proof of professionalism, including details about the treatment process.

6. ACKNOWLEDGMENTS

The authors gratefully acknowledge the support provided by the International College, Rajamangala University of Technology Krungthep, for this study.

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Financial feasibility of an EV rental business: cost-revenue analysis, EV policy framework, battery degradation forecasting, and the impact of OIC insurance regulations on Thai SME operators

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ABSTRACT

This study aims to (1) analyze the cost-revenue relationship in the EV rental business in Thailand; (2) assess the feasibility of the project using capital budgeting; and (3) conduct an analysis of risks with regard to the project using the Monte Carlo Simulation (MCS) and assess battery degradation using the Regression-calibrated Semi-Empirical model. The mixed methods approach was used, whereby qualitative data from three EV rental companies, one investment expert, one long-term company customer, and five documentary sources were analyzed with the help of Content Analysis and Theory Triangulation, and thereafter, the variables used were applied for quantitative modeling. As per the initial assumptions (65% utilization, 8% WACC), NPV is THB 0.69 million, IRR=10.4%, discounted payback period is 4.8 years. The Monte Carlo Simulation (10,000 iterations) shows that $P(NPV > 0)$ is approximately between 58 and 62%. The conditions of the Thai climate (32 degrees C) allow us to estimate the state of battery charge at Year 5 to be equal to 84-86%, which is more than the previously assumed value of 80%. The scenarios associated with OIC reduce the NPV by THB 192,000 if the price is increased by 20% and by approximately THB 256,000 if the battery indemnity rate at Year 5 is equal to 60%. Utilization rate is the most critical variable; below 62% renders NPV negative. Battery-risk-adjusted NPV is THB 0.20–0.45M. To our knowledge, this study is among the first to integrate capital budgeting, Monte Carlo simulation, battery degradation forecasting, and OIC insurance risk for Thai SME EV rental operations.

Keywords: Financial feasibility, EV rental business, Monte Carlo simulation, Battery degradation forecasting, OIC insurance policy

1. INTRODUCTION

Growing concern over climate change has driven national greenhouse-gas reduction targets. In 2023, 14 million Battery Electric Vehicles (BEVs) were registered worldwide—18% of all passenger vehicles sold—supporting Thailand's carbon-neutrality target by 2050. Thailand's EV Initiative 3.0 (2022–2023) provided THB 70,000–150,000 in subsidies per BEV, driving 85,299 new BEV registrations in 2023, up 524% from the prior two-year period. Under EV Initiative 3.5 (2024–2027), all public entities must lease rather than buy BEVs, and the rental car

business is projected to reach USD 1.89 billion by 2030 [8].

Prior research has separately examined EV rental profitability and pricing [1], conventional capital-budgeting methods [2], project-risk simulation [12], and battery degradation [10]. However, these research streams remain largely disconnected in the context of Thai SME rental operations, where local operating benchmarks and evidence on OIC-related insurance exposure remain limited. This study therefore addresses two practical gaps: limited Thai SME benchmark data and limited integrated evaluation of financial, stochastic, battery,

and regulatory risks. It contributes: (1) NPV, IRR, and discounted payback estimates based on active Thai SME operator data; (2) Monte Carlo simulation with 10,000 iterations; (3) a regression-calibrated semi-empirical battery degradation model linked to the financial effects of OIC Order 47/2023 [6]; and (4) an assessment of EV 3.0/3.5 and Thailand's Carbon Neutrality 2050 policy implications [14]. To our knowledge, this is among the first studies to integrate these four risk dimensions for Thai SME EV rental operations.

2. MATERIALS AND METHODS

2.1 Population and Sample

Participants were selected by purposive sampling for maximum information richness, per qualitative inquiry criteria [3]. Operators were required to have at least one year of active operation; the financial specialist, at least five years of Thai SME investment-appraisal experience. The final sample comprised three EV rental operators, one investment specialist, and one long-term B2B client, supplemented by five peer-reviewed and

regulatory sources. Data saturation was confirmed when no new thematic categories emerged after the third operator interview. All participants gave written informed consent per the ethics requirements of Rajamangala University of Technology Krungthep.

2.2 Data Collection and Analysis

This mixed-methods approach utilized qualitative evidence for the calibration of quantitative models on finances. Primary data came from technical and thorough interviews, evaluating the content validity of the study via two different specialists; and secondary data were obtained from scientific sources. In this regard, the Content Analysis and Theory Triangulation methods were applied across three frameworks: 1) deterministic capital budgeting processes such as NPV, IRR, and payback; 2) stochastic finance through Monte Carlo Simulation (involving 10,000 iterations); 3) Electrochemical degradation theory.

2.3 Financial Assumptions

Assumptions were calibrated to 2025–2026 Thai market data. See Table 1.

Table 1. Base-Case Financial Assumptions

No.	Category	Variable / Assumption	Base Case	Analysis Range	Source
1	Fleet	10 BEVs /THB 800,000/5 yrs	10/800K/5yr	5–20 units	Researcher's (2024)
2	Initial Invest.	Vehicles + charging infra	THB 9.5–10M	—	Researcher's (2024)
3	Annual OPEX	Elec/Maint/Ins/Admin	336K/200K/300K/1,444K	See Table 5	OIC 47/2023; PEA
4	Revenue	Short/Long-term/Ancillary	THB 1,800/day/65%/+5%	50–80%	Researcher's (2024)
5	Financial Criteria	WACC/Residual Value Yr5	8%/30%	6–10%	Capital Budgeting Theory
6*	OIC Insurance	Indemnity Yr1/annual decline/Yr5	100%/10 percentage points/year/60%	—	OIC Registrar Order 47/2023

* For vehicles aged more than four but not more than five years, the battery indemnity rate is 60%. The rate declines to 50% only when the vehicle is more than 5 years old, pursuant to OIC Registrar Order 47/2023.

2.4 Monte Carlo Simulation

A Truncated Normal Distribution was applied to six stochastic variables (Table 2) across $n = 10,000$ iterations. Each iteration sampled all

variables simultaneously, computing Net FCF, NPV (8% WACC), IRR (bisection, tolerance 0.0001%), and Discounted Payback Period.

$$NPV = -I_0 + \sum (FCF_t / (1+WACC)^t) + RV / (1+WACC)^T$$

Table 2. Stochastic Variables and Parameters for Monte Carlo Simulation

Variable	Distribution	μ	σ	[min, max]	Source
Utilisation Rate	Trunc. Normal	65%	0.08	[30%, 95%]	Researcher; Mordor Int. [8]
Daily Rental Rate (THB/day)	Trunc. Normal	1,800	300	[1,000, 4,000]	Interviews
Electricity (THB/kWh)	Trunc. Normal	4.20	0.50	[3.00, 7.00]	PEA/MEA [5]
EV Insurance (THB/unit/yr)	Trunc. Normal	30,000	5,000	[20K, 50K]	OIC 47/2023 [6]
Residual Value (%)	Trunc. Normal	30%	0.06	[10%, 55%]	Researcher's
Maintenance (THB/unit/yr)	Trunc. Normal	20,000	4,000	[10K, 45K]	Krungsri Res. [9]

2.5 Battery Degradation Forecasting (Semi-Empirical Battery Degradation Scenario Model)

A Semi-Empirical formula estimates the State of Health (SoH) of battery packs over 5 years from Calendar Age (M), Cycle Age (N), thermal stress (T), and Depth of Discharge (DoD), with a 50% lower bound imposed as the assumed end-of-life threshold, declining as each degradation factor accrues:

$$SoH(t) = \text{MAX}\{50\%, [1 - (\alpha \times \sqrt{M} + (\beta \times (f(T)) \times (f(DoD)))) \times N]\} \text{ of } 100\%$$

Where M = # of months of calendar age since vehicle was put into service, N = # of cumulative charge cycles that have occurred within the M months of calendar age, α = .00035, Calendar Age degradation factor, β = 0.0000012, Cycle Age degradation factor, $f(T) = e[0.03(T-25)]$, temperature stress function derived from the Arrhenius equation, $f(DoD) = (DoD)/(0.8)^{1.2}$, depth of discharge weight factor.

Table 3. Battery Degradation Model Parameters

Parameter	Base Case	Scenario Range	Source
Charge cycles/day	0.8	0.6–1.2	Field interviews
Avg. temperature (°C)	32	28–38	Meteorological Dept.
Depth of Discharge (DoD)	80%	70–85%	Birkel et al. [10]
Battery capacity (kWh)	60	40–100	Thai BEV data (2024)
Battery cost (THB/kWh)	4,500	3,500–6,000	BloombergNEF [11]
Min. SoH threshold	80%	—	Industry standard

2.6 Battery-Risk Adjusted NPV

$$NPV_{a \text{ e } j} = NPV_{m^c} - E[BRC] / (1+WACC)^5, \text{ where } E[BRC] = P(\text{replace}) \times$$

Cost(replace); P(replace) based on SoH at Year 5: <80% →0.70; 80–85% →0.30; ≥85% →0.10.

3. RESULTS AND DISCUSSION

3.1 Cost Structure

A fleet of 10 vehicles with three chargers requires THB 9.5–10.0M initial investment—approaching ICE costs by 2025 due to competition, while offering significantly lower OPEX (Table 1).

3.2 Revenue Structure

The revenue from B2B/B2G contracts helps generate predictable income, hence making it the

main source of revenue for the company when implementing the EV 3.5 directive.

3.3 Cash Flow Analysis (Base Case: 65% Utilization)

Projected overall five-year cash flow based on the 10-vehicle case, assuming the fleet utilization rate is 65%, and the WACC is 8%, is shown in Table 4.

Table 4. Projected Base-Case Cash Flows (10 Vehicles, 8% WACC, 5-Year Horizon) (THB)

Item	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5 + Salvage
A. Initial Investment	(9,500,000)	—	—	—	—	—
B. Total Revenue	—	4,484,025	4,484,025	4,484,025	4,484,025	4,484,025
C. Total OPEX	—	(2,280,000)	(2,280,000)	(2,280,000)	(2,280,000)	(2,280,000)
D. EBITDA	—	2,204,025	2,204,025	2,204,025	2,204,025	2,204,025
E. Tax and annual cash-flow adjustment	—	(60,805)	(60,805)	(60,805)	(60,805)	(60,805)
Net FCF (THB)	(9,500,000)	2,143,220	2,143,220	2,143,220	2,143,220	4,543,220
Cumulative PV CF	(9,500,000)	(7,515,537)	(5,678,071)	(3,976,714)	(2,401,384)	690,656

3.4 Deterministic Financial Assessment

Under the base case (65% utilization, 8% WACC, consistent with Thai listed-company cost-of-capital benchmarks [7]): NPV = THB 690,656 (positive; value-creating); IRR = 10.4% (exceeds WACC); Discounted Payback = 4.8 years; Break-even Utilization = 62%.

3.5 Sensitivity Analysis

Classification of variables by impact on NPV: (1) Utilization factor (variation of –THB 3.20M + THB 4.00M); (2) Daily rental cost (variation of –THB 1.75M + THB 2.84M); (3) Residual value; (4) WACC; (5) Power expenses; (6) OIC insurance scenario brings NPV to THB 0.43–0.50M.

Battery finance gap is calculated as difference between the estimated economic value kept by the battery and the sum of indemnity based on the OIC table:

$$\text{Financial gap}_t = C_\beta \times \text{MAX}(0, \text{SoH}_t - I_t),$$

where C_β is the replacement cost of a whole battery pack, SoH_t is modeled state of health of a battery, and I_t is applicable OIC battery indemnity rate as of year t .

Table 5. Sensitivity Analysis Results

Variable / Scenario	NPV (THB)	IRR (%)	Δ NPV	Signal
1. Utilization Rate (Highest Impact)				
Best case: 80%	3,996,000	21.5%	+3,305,000	✓
* Base case: 65%	691,000	10.4%	—	●

Worst case: 50%	(3,198,000)	-3.8%	-3,889,000	X
2. Daily Rental Rate				
+15% (THB 2,070/day)	2,839,000	17.7%	+2,148,000	✓
-15% (THB 1,530/day)	(1,752,000)	1.7%	-2,443,000	X
3. OIC Insurance *				
Premium +20%	499,000	9.8%	-192,000	⚠
Battery indemnity Yr5 = 60%	≈435,000	9.6%	≈-256,000	⚠
4. Residual Value				
40% of purchase price	1,235,000	12.2%	+544,000	✓
15% of purchase price	(126,000)	7.5%	-817,000	X

* Registrar Order 47/2023 indicates OIC variables, ✓ NPV > Base, ⚠ Reduced but positive, and X NPV < 0.

Under the 60% Year 5 battery indemnity case, THB 256,000 has to be reduced based on NPV. At 8% discount rate, the nominal cash flow will be decreased to roughly THB 376,148 in Year 5. Thus, net cash flow in Year 5 will decrease to THB 4,543,220 - THB 4,167,072, resulting in NPV of THB 434,656 and IRR 9.56%. Cash flows in Years 0-4 are unaffected.

3.6 Monte Carlo Simulation Results

As per 10,000 repetitions: Average NPV ≈ THB 0.70 million, median at THB 0.62 million, standard deviation THB 1.55 million, and 90% simulation range (5th-95th percentile): -THB 1.85 million to +THB 3.32 million. P[NPV > 0] remains within 58% to 62% according to three distribution

assumptions (truncated normal, triangular, uniform), hinting at 38-42% of probability of loss that cannot be calculated using deterministic methods alone [12]. The overall distribution is shown in Figure 1, and the global sensitivity analysis allowed us to define main input variables [13]. In the current simulation, it turned out that utilization rate has the highest influence on the NPV.

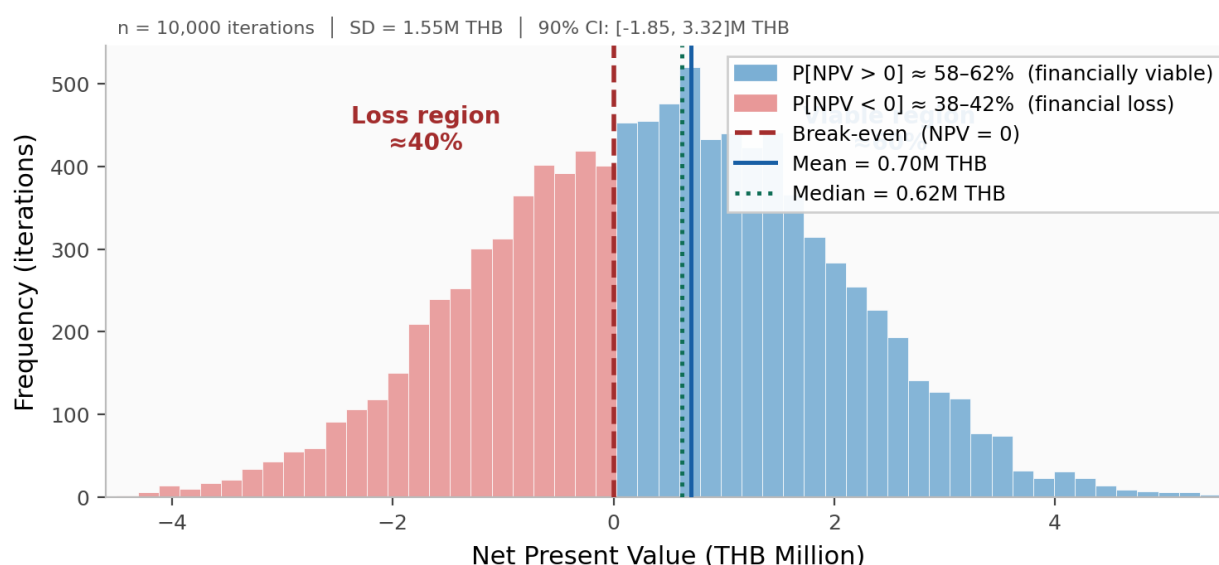


Figure 1. Probability distribution of NPV outcomes from Monte Carlo Simulation (n = 10,000 iterations). The vertical dashed line denotes break-even (NPV = 0). Blue bars represent financially viable outcomes; red bars represent loss scenarios. Summary

statistics: Mean = THB 0.70M; Median = THB 0.62M; SD = THB 1.55M; 90% CI = [–THB 1.85M, +THB 3.32M]. Source: Authors' simulation.

3.7 Battery Degradation Results

Under the assumption of the original scenario (temperature = 32°C, cycles = 0.8 per day, depth of discharge = 80%), the state of health in year 5 will be 84% – 86%, thus exceeding the required commercial threshold of 80%. The estimated driving

range will reduce from 400 km to approximately 339 km. In year 5, the OIC battery indemnity is equal to 60%, while the modeled battery maintains the state of health of around 84%. Such difference indicates that some degree of financial risk will still remain for the operator.

Table 6. Projected Annual SoH vs. OIC Indemnity Rate

Year	SoH (%)	Estimated Range (km)	OIC Indemnity Rate (%)	Battery Economic Value (THB thousand/unit)	Financial Gap (THB/unit)
0	100.0	400	100	270	0
1	~96.5	~386	100	~261	0
2	~93.2	~373	90	~252	8,640
3	~90.1	~360	80	~243	27,270
4	~87.3	~349	70	~236	46,710
5	~84.8	~339	60	~229	66,960

Notes: The new battery replacement cost was estimated at THB 270,000 per unit (60 kWh × THB 4,500/kWh). Battery economic value was estimated as the replacement cost multiplied by the modeled SoH. The financial gap was calculated as:

$\text{Financial Gap}_t = C_{\beta} \times \text{MAX}(0, \text{SoH}_t - I_t)$, where C_{β} is the new battery replacement cost, SoH_t is the modeled state of health, and I_t is the applicable OIC indemnity rate in year t . Thus, the Year-5 financial gap is THB 270,000 × (84.8% – 60%) = THB 66,960 per vehicle, or THB 669,600 for the 10-vehicle fleet, before discounting and probability adjustment. OIC indemnity rates are based on OIC Registrar Order 47/2023 [6].

3.8 Battery-Risk Adjusted NPV and Discussion

Battery-risk-adjusted NPV is estimated at THB 0.20–0.45M (mean), with a 48–55% probability that $\text{NPV}_{\text{aej}} > 0$. This implies: (1) the deterministic NPV of THB 0.69M is overly optimistic as it ignores stochasticity and battery risk; (2) viability probability drops below 50% once risk is considered; and (3) operators must budget THB 0.25–0.50M for Year 4–5 battery risk.

The model is feasible above 62% fleet utilization in an active growth sector [8] supported by government policy [14]. The IRR of 10.4%—only 2.4% above the 8.0% WACC—leaves little margin for error, and the 4.8-year payback (near the project horizon) signals SME liquidity pressure. At Year 5, the difference between the modeled battery SoH of

84.8% and the OIC indemnity rate of 60% represents a gross financial exposure of approximately THB 66,960 per vehicle, or THB 669,600 for the 10-vehicle fleet, before discounting and probability adjustment. Separately, the two OIC-related scenarios in Table 5 reduce NPV by THB 192,000 under a 20% premium increase and approximately THB 256,000 under a 60% Year-5 battery indemnity rate, indicating the need for a pre-funded insurance and battery-risk reserve [6].

Theory Triangulation [3,4] identifies three risk layers that no single framework reveals: (1) the deterministic model defines viability without probability; (2) Monte Carlo quantifies the 38–42% loss probability omitted by the point estimate [12]; and (3) Battery Degradation theory shows physicochemical drivers (Arrhenius temperature and

DoD factors) that pull NPV below the deterministic value. Consistent with Denzin [3] and Thurmond [4], divergent results deepen understanding of risk rather than signal assessment failure. The importance of utilization and pricing is consistent with prior EV-rental profit modeling [1] and extends stochastic capital-budgeting evidence [2,12] to Thai SMEs; practically, secured B2B/B2G contracts and a pre-funded battery reserve are entry preconditions.

4. CONCLUSIONS

The EV rental sector is financially viable under disciplined operational management: NPV THB 0.69M, IRR 10.4%, Payback 4.8 years. OIC-related scenarios reduce the base-case NPV by approximately THB 0.19–0.26 million. Although the project remains financially viable, SME operators should maintain a separate reserve for uninsured battery value and potential replacement costs during Years 4–5. Recommended actions: (1) maintain $\geq 70\%$ utilisation via B2B/B2G contracts; (2) build a THB 250,000–500,000 battery reserve for years 4–5; (3) limit DoD below 70% and use shaded parking and off-peak charging to hold SoH at 89–91%; (4) register all drivers (max five) per OIC Order 47/2023; and (5) adopt electronic fleet management to cut administrative costs.

Future research should (1) add quantitative datasets to establish sector-wide generalizability; (2) compare economics across vehicle classes (sedan, SUV, van); (3) assess the impact of ending EV 3.5 subsidies; and (4) calibrate battery modeling against actual Thai fleet data.

5. ACKNOWLEDGMENTS

The authors are grateful to the International College, Rajamangala University of Technology Krungthep, for its institutional support and the

participants of the study for their contribution of data and advice.

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Antecedents of impulse buying intention in TikTok live commerce: mediating roles of flow experience and perceived enjoyment within a Stimulus-Organism-Response framework

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ABSTRACT

This research investigates the effects of TikTok live commerce stimuli (i.e., streamer & content quality, real-time interaction, and perceived scarcity) on consumers' intention to buy impulsively (IBI) through their flow experience and perceived enjoyment, all within the context of a Stimulus-Organism-Response (S-O-R) Framework as well as Uses and Gratifications Theory. Data from 108 Thai TikTok live consumers were analyzed using Consistent Partial Least Squares (PLSc). Streamer expertise and content quality were empirically indistinguishable (HTMT > 1.0) and were merged into a single SCQ construct. The measurement model showed adequate reliability (composite reliability: 0.825–0.912; AVE: 0.541–0.654; max HTMT = 0.865) and acceptable fit (SRMR = 0.083). Four of six hypotheses were supported: SCQ predicted flow experience ($\beta = 0.645$, $p < 0.001$; H1), real-time interaction predicted perceived enjoyment ($\beta = 0.538$, $p < 0.001$; H2), and both flow experience ($\beta = 0.419$, $p < 0.001$; H4) and perceived enjoyment ($\beta = 0.273$, $p = 0.032$; H5) predicted IBI, explaining 41.1% of its variance. Perceived scarcity did not predict perceived enjoyment (H3), and cultural collectivism did not moderate the flow-IBI relationship (H6). Contributions include an empirically grounded S-O-R application to Thai TikTok live commerce and practical insights on the primacy of streamer/content quality and real-time interaction as drivers of impulse purchases.

Keywords: TikTok live commerce, impulse buying intention, Stimulus-Organism-Response (S-O-R), flow experience, perceived enjoyment, cultural collectivism

1. INTRODUCTION

Thailand's social commerce market reached \$4.38B (USD) in 2024 with an estimated growth rate of 10.2% CAGR (Compound Annual Growth Rate) until 2030 due to high internet penetration (91%) and social media usage (71%) [1][2]. TikTok live commerce uses short-term entertainment through an actor/entertainer (called a "streamer") while providing a way for fans/consumers to make purchases immediately; therefore, impulse buying (i.e., purchases that occur suddenly and unexpectedly because of a person's strong desire to buy) happens frequently as a result

of this format [3]. Factors shaping the formation of impulse buying on live streaming platforms consist of the credibility of the streamer, the level of quality of the content, the frequency of interaction between the viewer and streamer in real time, and the viewer's perceived scarcity of the product being featured on the platform [4].

In addition to the S-O-R framework, this study is informed by Uses and Gratifications Theory (UGT), which explains that individuals actively select media platforms to satisfy specific psychological and social needs, including information seeking, entertainment, and social interaction [31]. Within TikTok Live Commerce,

viewers voluntarily participate in live-stream sessions because they seek product information, enjoyable experiences, and interactive communication with streamers and other viewers. These gratifications stimulate psychological responses such as flow experience and perceived enjoyment, which subsequently influence purchasing behavior. Accordingly, UGT complements the S-O-R framework by explaining why consumers engage with live commerce before the stimulus–organism process occurs.

This study therefore pursues four objectives: (1) examine the effect of streamer & content quality (SCQ) on flow experience; (2) examine the effects of real-time interaction and perceived scarcity on perceived enjoyment; (3) examine the effects of flow experience and perceived enjoyment on IBI; and (4) test cultural

collectivism as a moderator of the organism–response relationship, as illustrated in the proposed framework (Figure 1). Data from 108 Thai TikTok live consumers are analyzed via PLSc, contributing an S-O-R extension to collectivist contexts and practical guidance for live-commerce operators and policymakers in Thailand.

Guided by the S-O-R framework and Uses and Gratifications Theory, this study proposes that streamer & content quality, real-time interaction, and perceived scarcity represent environmental stimuli that satisfy consumers' informational, entertainment, and social interaction needs. These gratifications enhance consumers' psychological states (flow experience and perceived enjoyment), which subsequently increase impulse buying intention.

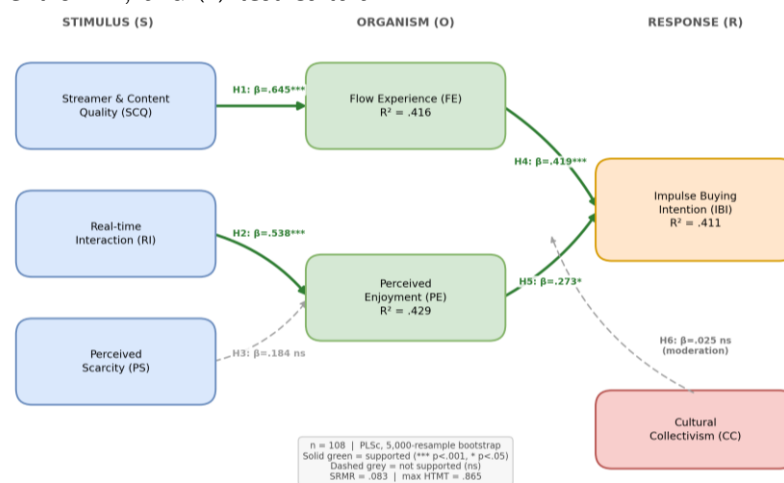


Figure 1. Conceptual research framework with standardized path coefficients, significance, and R^2 for endogenous constructs. Solid arrows = supported hypotheses; dashed arrows = not supported.

2. MATERIALS AND METHODS

2.1 Research design and sample

This study adopts a quantitative cross-sectional design using a self-administered online questionnaire. The target population comprises Thai consumers aged 18+ who watched and purchased products via TikTok Live within the prior three months. Purposive and snowball sampling

were used across TikTok Shop Thailand community groups, academic/business networks via Google Forms, and direct outreach to Thai micro-influencers. A sample of 108 valid responses was collected (originally targeting 400 respondents). Based on an a priori G*Power analysis (effect size $f^2 = 0.15$, $\alpha = 0.05$, statistical power = 0.80), the minimum required sample size was 85 respondents [9]. Therefore, the final sample exceeded the minimum requirement for conducting the PLSc

analysis. Screening questions, attention checks, and a minimum completion time of five minutes were used to ensure data quality.

Two a priori approaches were used to determine the adequacy of sample size for variance-based SEM [9,10]. The first was based on the most complex endogenous construct that defined the requirement of sample size, which was impulse buying intention (the predictor constructs include flow experience, perceived enjoyment, cultural collectivism, and interaction effects) as defined by Hair et al. [9]. Sample size estimates for power = 0.80, $\alpha = 0.05$, and $f^2 = 0.15$ using G*Power indicated that the minimum required sample size would be $n = 85$; therefore, there was more than sufficient sample size to perform the analyses. The second method to estimate sample size was the inverse square root method [10], which calculated that $n = 108$ would have provided 80% power to detect minimum path coefficients of $|\beta| \approx 0.24$ for the hypothesized effects found significant later, thus showing that there was sufficient sample size to perform the analyses. Overall, the realized sample sizes were sufficient for supporting the direct-effect hypotheses; however, only moderate power was available to detect interaction effects, which is further discussed in Section 4.

2.2 Measurement instrument

The 34-item questionnaire contained items developed from various validated scales and was measured against an Asian consumer demographic reflecting a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree) [9]. Content validity was established through three subject-matter experts who judged that the CVI values for individual items would exceed 0.80, and a pilot test with a sample of 30 respondents demonstrated that all constructs exceeded a Cronbach's Alpha of 0.70.

Following data collection, it was determined that the items measuring streamer expertise and content quality were statistically

indistinguishable ($HTMT > 1.0$) and were therefore considered to be part of one combined eight-item streamer & content quality construct, which is appropriate given their status as dimensions of live-stream stimulus qualities in the S-O-R model.

It was also determined that one of the cultural collectivism items had a low load (0.600) and was therefore eliminated from the final analysis of 33 items.

2.3 Analysis via PLSc — ADANCO 2.4.1

Consistent Partial Least Squares (PLSc) was employed using ADANCO 2.4.1 [11], chosen over regular PLS because it (1) corrects for attenuation bias in reflective models [12], (2) reports a complete set of fit indices—SRMR, RMS_theta, NFI, CFI—and (3) suits the study's fully reflective constructs. Following Anderson & Gerbing's two-stage approach [13], the analysis applies established quality thresholds: factor loadings, composite reliability, and Cronbach's alpha each ≥ 0.70 [9]; Discriminant validity was assessed using the Heterotrait-Monotrait Ratio (HTMT), adopting the recommended threshold of $HTMT < 0.90$ for conceptually related reflective constructs, as suggested by Hair et al. [9] and Henseler et al. [14]; $SRMR < 0.08$ and $RMS\_theta < 0.12$ [11]; and $VIF < 3.3$ [9].

2.4 Moderation analysis

To see if there was a moderating influence from cultural collectivism, the moderating effects were assessed by using the native orthogonalizing method available in ADANCO. Following stage one of the data analysis, two interaction variables were generated automatically: the interactives of flow experience and collectivism and perceived enjoyment and collectivism. These were assessed for significance using 5,000 samples from bootstrap. Common Method Bias was assessed using Harman's single-factor test, separating predictors from the criterion.

3. RESULTS AND DISCUSSION

3.1 Measurement model assessment

Following Anderson and Gerbing's two-stage approach [13], indicator loadings ranged from 0.637 to 0.860, with most exceeding the 0.70 threshold [9]; four items loading 0.64–0.69 were retained since removal did not improve composite

reliability or AVE (Table 1). Composite reliability (ρ_c) ranged from 0.825 to 0.912 and Dijkstra–Henseler's ρ_A from 0.727 to 0.894, both above 0.70 [12]; Cronbach's alpha ranged from 0.718 to 0.890. After removing one low-loading collectivism item, AVE exceeded 0.50 for all constructs (0.541–0.654), confirming convergent validity.

Table 1. Construct Reliability and Convergent Validity

Construct	Loading Range	ρ_A	ρ_c (CR)	α	AVE
SCQ (Streamer & Content Quality)	0.679–0.844	0.894	0.912	0.890	0.566
RI (Real-time Interaction)	0.680–0.810	0.748	0.837	0.740	0.563
PS (Perceived Scarcity)	0.706–0.858	0.829	0.865	0.794	0.617
FE (Flow Experience)	0.747–0.860	0.827	0.883	0.823	0.654
PE (Perceived Enjoyment)	0.754–0.821	0.813	0.874	0.807	0.633
IB (Impulse Buying Int.)	0.637–0.800	0.801	0.856	0.790	0.544
CC (Cultural Collectivism)	0.690–0.785	0.727	0.825	0.718	0.541

Notes: ρ_A = Dijkstra–Henseler's rho; ρ_c = Jöreskog's rho (Composite Reliability); α = Cronbach's Alpha; AVE = Average Variance Extracted; SCQ = merged streamer expertise and content quality construct. All reliability and AVE values exceed recommended thresholds [9,12].

3.2 Discriminant validity

Heterotrait-Monotrait Ratio (HTMT) was used to test discriminant validity in the seven original constructs. In the original seven constructs, the construct of streamer's experience and construct of content quality produced an HTMT above the value of one (1.0), indicating that they are empirically unidentifiable. As such, the two constructs have been combined into a new SCQ (Streamer & Content Quality) construct (as discussed in Section 2.2). In the re-specified model, the highest HTMT value was 0.865, observed between Real-time Interaction and Flow Experience. This value remained below the recommended 0.90 threshold for conceptually related reflective constructs [9,14], indicating satisfactory discriminant validity. Furthermore, the Fornell–Larcker criterion confirmed that the square

root of each construct's AVE exceeded its correlations with other constructs, providing additional evidence of discriminant validity.

3.3 Structural model results

The overall fit for the saturated model using the Standardized Root Mean Square Residual Error (SRMR) was 0.083, which is slightly above the more restrictive 0.08 criteria for the fit of PLS path models [11]; thus, the fit of the overall model was within the acceptable range of < 0.10 . The endogenous constructs analyzed (R^2), Flow Experience (0.416), Perceived Enjoyment (0.429), and Impulse Buying Intention (0.411; R^2 adj = 0.410, 0.419 & 0.400 respectively) all had moderate levels of explained variance. The path coefficients calculated from bootstrapping with 5,000 resamples are noted in Table 2.

Table 2. Structural Model Results and Hypothesis Testing

H	Path	β	Std. Error	t-value	p-value	Cohen's f^2	Decision
H1	SCQ $\rightarrow$ FE	0.645	0.065	9.967	<0.001	0.711	Supported **
H2	RI $\rightarrow$ PE	0.538	0.094	5.752	<0.001	0.363	Supported **
H3	PS $\rightarrow$ PE	0.184	0.105	1.750	0.083	0.043	Not Supported
H4	FE $\rightarrow$ IB	0.419	0.113	3.714	<0.001	0.152	Supported **
H5	PE $\rightarrow$ IB	0.273	0.126	2.168	0.032	0.064	Supported *
H6	FE $\times$ CC $\rightarrow$ IB	0.025	0.069	0.359	0.720	0.001	Not Supported

Notes: IB = Impulse Buying Intention; FE = Flow Experience; PE = Perceived Enjoyment; SCQ = Streamer & Content Quality; RI = Real-time Interaction; PS = Perceived Scarcity; FE $\times$ CC = Flow Experience $\times$ Cultural Collectivism interaction. Bootstrapping: 5,000 resamples. * $p < 0.05$; ** $p < 0.01$.

3.4 Moderation analysis

Cultural collectivism's moderating effect on the Flow Experience $\rightarrow$ IBI path was tested using the orthogonalizing approach [9]. The interaction term (Flow Experience $\times$ Cultural Collectivism) was non-significant ($\beta = 0.025$, $t = 0.359$, $p = 0.720$, $f^2 = 0.001$), indicating no significant moderation; H6 is therefore not supported. Given the modest sample ($n = 108$), limited power for detecting interaction effects may partly explain this null result, warranting re-examination with a larger field sample.

The findings also support the assumptions of Uses and Gratifications Theory. Real-time interaction and high-quality streamer content appear to satisfy consumers' needs for entertainment, information, and social engagement, thereby enhancing perceived enjoyment and flow experience. These psychological gratifications subsequently increase consumers' impulse buying intention. Thus, the present study demonstrates that UGT complements the S-O-R framework by explaining consumers' motivations for engaging with

TikTok Live Commerce before their emotional and behavioral responses occur.

4. CONCLUSIONS

This study extends the Stimulus–Organism–Response (S-O-R) framework by incorporating insights from Uses and Gratifications Theory to explain impulse buying intention in TikTok Live Commerce among Thai consumers. The findings indicate that streamer & content quality and real-time interaction satisfy consumers' informational, entertainment, and social interaction needs, thereby strengthening flow experience and perceived enjoyment, which subsequently increase impulse buying intention. These findings demonstrate that UGT complements the S-O-R framework by explaining consumers' motivations for participating in live commerce, while S-O-R explains how these motivations translate into psychological responses and purchasing behavior.

However, Perceived Scarcity did not predict Perceived Enjoyment (H3), and Cultural Collectivism did not moderate the flow–IBI relationship (H6). These findings broadly support the S-O-R framework in a Thai TikTok Live context, highlighting streamer/content quality and real-time interaction as the primary levers for practitioners. Some limitations of this study are that we had a

very small sample size, which lowers our statistical power, and the SRMR value was just above what is considered reasonable according to the cutoff. Future studies need to (a) try to replicate our findings with a larger sample size, (b) improve the classification of collectivism, and (c) conduct a study that will allow us to compare across different platforms in ASEAN countries.

5. ACKNOWLEDGMENTS

The authors thank the International College, Rajamangala University of Technology Krungthep, for institutional support and all survey participants.

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The Influence of Social Media Key Opinion Leaders on Generation Z's Travel Intentions: Evidence from Social Media Users in China and Thailand

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ABSTRACT

Key opinion leaders (KOLs) have become central intermediaries in how young consumers gather, interpret, and act upon tourism information, yet how the different characteristics of their content translate into travel intention remains underspecified. Drawing on the Stimulus–Response logic of the S–O–R tradition and on Source Credibility Theory, this study models KOL communication as a multidimensional stimulus and tests the direct influence of two groups of KOL characteristics—source-related characteristics (credibility and authenticity) and content-related characteristics (informativeness and interactivity)—on Generation Z's travel intention. A self-administered online survey yielded 836 valid responses from Generation Z social media users in China and Thailand who actively consumed tourism-related KOL content. The data were analyzed using confirmatory factor analysis and structural equation modeling. The measurement model showed satisfactory reliability and validity (CR = .898–.951; AVE = .710–.829), and the structural model fitted the data well ($\chi^2/df = 2.18$; RMSEA = .047; CFI = .971; TLI = .962; SRMR = .038). Both groups of KOL characteristics were positively and significantly related to travel intention, with content-related characteristics ($\beta = .41$, $p < .001$) exerting a somewhat stronger effect than source-related characteristics ($\beta = .34$, $p < .001$), together explaining a substantial share of the variance in intention ($R^2 = .43$). The findings indicate that tourism campaigns aimed at Generation Z benefit from KOL content that is both credible and authentic and, in particular, genuinely informative and interactive.

Keywords: key opinion leaders, Generation Z, travel intention, source credibility, content characteristics, structural equation modeling

1. INTRODUCTION

Social media has reshaped how young consumers learn about destinations and decide where to go. Where travel agencies, brochures, and official advertisements once mediated destination knowledge, platforms such as Instagram, TikTok, Douyin, Xiaohongshu, and YouTube now place visual, interactive, and personalized travel content in front of users daily, often before any deliberate search has begun [1, 2]. Within this environment, a particular type of actor has acquired disproportionate influence: the social media key opinion leader (KOL), or influencer. Through personal storytelling, visual narrative, and a perceived authenticity that conventional advertising struggles to imitate, KOLs shape how audiences imagine a place long before a trip is contemplated [3, 4].

The persuasive reach of KOLs is now well documented in marketing and consumer-behavior research, where credibility, authenticity, and parasocial interaction recur as attributes that influence attitudes and intentions [5, 6]. That evidence base, however, was built largely around fashion, cosmetics, and general consumer products, and it tends to treat the influencer's effect as a fairly direct path from exposure to purchase intention. Tourism does not fit this template comfortably. A travel decision is bound up with imagination, anticipated experience, and the slow accretion of attitude; it is emotionally weightier and temporally more extended than the decision to buy a lipstick [7]. The mechanism that links KOL communication to a travel intention is therefore unlikely to be the immediate, single-step process that much of the purchase-intention literature implies.

The stakes of understanding this shift are not merely academic. Tourism is among the world's largest service industries, and destination marketing has decisively migrated to social platforms, where official tourism bodies now compete for attention alongside individual creators [8]. Generation Z is the segment that matters most for the sector's medium-term future: its members are entering their peak earning and traveling years, and they reach destinations through feeds rather than through brochures. For this cohort, the influential voice is rarely the institutional advertiser and increasingly the trusted

creator, which makes the psychology of KOL influence a question of commercial as much as theoretical interest.

Two gaps follow from this. First, despite the emotional and experiential character of tourism, comparatively little influencer research examines travel specifically, and fewer studies still distinguish which characteristics of KOL content actually raise travel intention rather than simply asking whether exposure does. Second, KOL communication is often treated as a single undifferentiated quality, even though its persuasive force plausibly rests on distinct bundles of characteristics—those tied to the influencer as a source, such as credibility and authenticity, and those tied to the content itself, such as informativeness and interactivity—whose relative weight for Generation Z's travel intention is rarely compared directly.

This study addresses these gaps by treating KOL communication as a multidimensional stimulus and testing the direct effects of its source- and content-related characteristics on Generation Z's travel intention. Generation Z, the cohort born between 1997 and 2012 [11], is the appropriate population: its members are the first to have come of age entirely within the smartphone era, and their travel imagination is unusually saturated by influencer-mediated content [12]. The study pursues two objectives: to examine how source-related KOL characteristics (credibility and authenticity) relate to travel intention, and to examine how content-related KOL characteristics (informativeness and interactivity) relate to travel intention. In doing so, it offers a more differentiated account of how influencer communication shapes digital tourism behavior among young consumers.

2. THEORETICAL BACKGROUND AND HYPOTHESES

2.1 The Stimulus–Organism–Response framework

The Stimulus–Organism–Response (S–O–R) framework provides the broad organizing architecture for this study. Originating in environmental psychology, the framework holds that external stimuli (S) act on internal states (O), which, in turn, drive behavioral responses (R) [13, 14, 15]. The present study focuses on the stimulus–response link within this tradition: it treats tourism-related KOL

communication as the stimulus and travel intention as the response. It examines how the characteristics of that stimulus directly relate to intention. The fuller internal-processing mechanisms that the framework also allows for are deliberately set aside here, leaving the direct stimulus–response relationships as the focus of this study.

Source Credibility Theory specifies why some communicators persuade and others do not: a message’s impact depends on the receiver’s perception of the source’s trustworthiness, expertise, and attractiveness [16, 17]. In the influencer setting, this source-based persuasion is complemented by qualities of the content itself—how useful and how engaging it is—so that both who is speaking and what is being said contribute to the audience’s receptiveness to the recommendation [4, 6]. These two literatures motivate the grouping of KOL communication into source-related and content-related characteristics developed below.

2.2 KOL communication as a multidimensional stimulus

KOL communication is conceptualized here not as a single quality but as a set of perceived characteristics of tourism-related influencer content, which fall into two groups. Source-related characteristics concern the influencer as a communicator: credibility captures the perceived trustworthiness and expertise of the influencer [17, 5], and authenticity concerns the perceived sincerity and genuineness of the content, the sense that the influencer shares real experience rather than scripted promotion [3, 21]. Content-related characteristics concern the message itself: informativeness reflects the practical usefulness and detail of the travel information conveyed [4], and interactivity refers to the perceived responsiveness and engagement between influencer and follower [19]. Grouping the four dimensions in this way distinguishes the persuasive force that derives from the source from that which derives from the content, while recognizing that audiences experience both together.

Dual-process models of persuasion help explain why both groups of characteristics matter. The Elaboration Likelihood Model distinguishes between a central route, in which the receiver scrutinizes the quality of the arguments, and a peripheral route, in which cues such as

source attractiveness and likeability carry the message [22]. Short, visually saturated travel content consumed in a scrolling feed engages both routes: content-related cues supply the substance that supports more effortful processing, while source-related cues such as the influencer’s credibility and warmth do peripheral persuasive work. Both, on this account, should feed forward into travel intention.

Source-related characteristics are expected to raise travel intention because a trustworthy, expert, and authentic influencer lends the destinations they feature a borrowed credibility: audiences are more willing to act on a recommendation when they believe the person making it is sincere and knowledgeable [17, 3]. For Generation Z, whose exposure to sponsored content has sharpened its sensitivity to inauthenticity, perceived credibility and authenticity are especially likely to convert attention into a genuine intention to travel. This reasoning yields the first hypothesis.

H1. Source-related KOL characteristics (credibility and authenticity) are positively related to travel intention.

Content-related characteristics are expected to increase travel intention because the substance of what an influencer conveys provides the audience with concrete grounds for action. Informative content provides the practical details—destinations, routes, costs, and logistics—that turn a vague appeal into a feasible plan. In contrast, interactive content, through responsiveness and dialogue, deepens engagement and personal relevance [4, 19]. For a digitally native cohort that actively researches trips through social platforms, useful and engaging content is a direct spur to travel intention. This reasoning yields the second hypothesis.

H2. Content-related KOL characteristics (informativeness and interactivity) are positively related to travel intention.

2.3 Conceptual framework

Figure 1 presents the model. KOL communication, specified through its four dimensions grouped into source-related characteristics (credibility and authenticity) and content-related characteristics (informativeness and interactivity), acts as the stimulus; travel intention is the behavioral response. The two groups of characteristics are

modeled as direct predictors of travel intention, corresponding to H1 and H2.

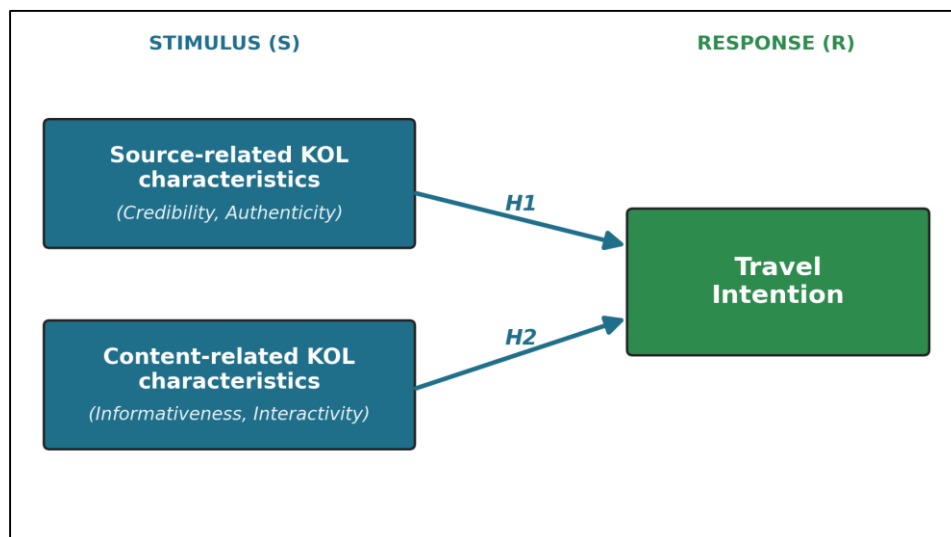


Figure 1. Conceptual framework: source-related and content-related KOL characteristics as direct predictors of Generation Z’s travel intention.

2.4 Synthesis of prior empirical evidence

The hypotheses do not arise in a vacuum. A growing body of research on influencers and tourism has examined how influencer characteristics shape consumer and travel outcomes. Table 1 synthesizes representative studies, the variables they connect, and their principal

findings, so that the contribution of the present model can be read against what is already known. Across this work, both the credibility of the source and the value of the content recur as drivers of behavioral intention. Yet, the two are rarely weighed against each other specifically for travel—the gap this study addresses.

Table 1. Synthesis of representative empirical studies on KOL influence and travel/consumer outcomes.

Study	Context	Focal links	Method	Main finding
Casaló et al. [3]	Instagram, Spain	Credibility, originality → opinion leadership → intention	Survey, SEM	Originality and credibility drive opinion leadership and behavioral intention.
Sokolova & Kefi [6]	Instagram/YouTube, France	Credibility, parasocial interaction → purchase intention	Survey, PLS-SEM	Parasocial interaction outweighs credibility in moving intention.
Lou & Yuan [4]	Social media, USA	Message value, source credibility → trust → intention	Survey, SEM	Informative value and credibility raise trust in branded content.
Ladhari et al. [30]	YouTube vlogs, Canada	Homophily, emotional attachment, expertise → influence	Survey, SEM	Emotional attachment, not expertise, best explains influence.
HoSany & Gilbert [7]	HeDonic destinations, UK	Emotional experience → satisfaction/intention	Survey, SEM	Tourist emotion is a strong antecedent of behavioral response.
Present study	KOL travel content, China & Thailand	Source- & content-related KOL characteristics → travel intention	Survey, SEM (N=836)	Both source- and content-related KOL characteristics directly raise travel intention.

3. METHODOLOGY

3.1 Research design and philosophical orientation

The study adopts a quantitative, cross-sectional survey design within a positivist orientation and a deductive logic: established theory generates hypotheses, which are then tested against structured data [35]. The design suits the

research aim, which is to test theoretically specified relationships among several latent constructs rather than to generate theory inductively. Cross-sectional data cannot establish temporal sequence, a limitation revisited below, but they are standard in consumer-behavior and tourism research for evaluating posited structural relationships. Structural equation modeling (SEM) was chosen as the principal analytic method because it accommodates multiple latent variables, a multidimensional conceptualization of the focal stimulus, and the joint testing of measurement and structural relations within a single framework [36, 37].

3.2 Population and sample

The target population comprised Generation Z social media users in China and Thailand who actively consume tourism-related content and have been exposed to tourism-related KOL communication. Following Dimock [11], Generation Z was defined as the 1997–2012 birth cohort and, for this study, operationalized as individuals aged 18 to 28 at the time of data collection; the lower bound reflects informed-consent requirements. Because no sampling frame exists that enumerates behavior-specific Generation Z social media users, a non-probability purposive sampling strategy was adopted, supplemented by snowball referrals from initial seed participants. The population was therefore conceptualized in terms of theoretical relevance—i.e., eligible, behaviorally appropriate users—rather than population-level representativeness.

Eligibility was confirmed through screening questions at the start of the questionnaire: respondents had to fall within the defined age range, use at least one major social media platform, and have viewed tourism-related KOL content. Incomplete or internally inconsistent responses were removed. The final sample comprised 836 valid respondents drawn from both countries. This size is comfortably adequate for SEM with multidimensional constructs, exceeding the conventional heuristics for stable estimation with models of this complexity [36, 37].

3.3 Measures

All constructs were measured with multi-item reflective scales adapted from established sources to the

tourism-KOL context, each rated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). A five-point format was selected for its balance of sensitivity and clarity in online self-completion. KOL communication was measured through its four dimensions, grouped into source-related characteristics—credibility (three items [17]) and authenticity (three items [3])—and content-related characteristics—informativeness (three items [4]) and interactivity (three items [19]). Travel intention, the dependent variable, was measured with three items on the self-reported likelihood, willingness, and consideration of visiting destinations featured by the influencer [32]. Table 2 summarises the constructs, their item counts, and source scales.

Table 2. Constructs, dimensions, item counts, and source scales.

Construct / dimension	Items	Source
Credibility	3	Ohanian [17]
Authenticity	3	Casaló et al. [3]
Informativeness	3	Lou & Yuan [4]
Interactivity	3	Labrecque [19]
Travel intention	3	Lam & Hsu [32]

3.4 Translation, validity, and common-method bias

Because respondents were drawn from two language communities, semantic equivalence was a priority. The original English instrument was translated into Simplified Chinese and Thai and then independently back-translated by bilingual translators, following Brislin's [38] procedure; discrepancies were reconciled through discussion before the instrument was finalized. Item wording was adjusted for greater contextual clarity, while the overall structure remained constant across versions, ensuring that respondents in both countries answered conceptually equivalent items.

Content validity was established by drawing on validated prior scales and by expert review: academics with experience in tourism marketing and consumer behavior evaluated the relevance, wording, and structure of the items, and refinements were made on their advice. A pilot test with 60 eligible respondents (30 in China, 30 in Thailand) checked item clarity, response flow, and preliminary reliability before full fieldwork. Construct validity was assessed through confirmatory factor analysis,

and reliability through Cronbach's α and composite reliability (CR), with convergent validity gauged by standardized loadings and average variance extracted (AVE) and discriminant validity by the Fornell–Larcker criterion [39, 40]. Because the data were self-reported and collected through a single instrument, common-method bias was addressed procedurally—through anonymity assurances, varied item wording, and clear instructions intended to reduce evaluation apprehension and consistency motifs [41].

3.5 Data collection, ethics, and analytical strategy

Data were collected via an online self-administered questionnaire distributed to eligible users in both countries, an approach well matched to a digitally active target population and to the geographic spread of the sample. The instrument began with screening items, proceeded to the construct measures, and concluded with demographic questions. Participation was voluntary and anonymous. Before beginning, respondents read an informed-consent statement explaining the study's purpose, the voluntary nature of participation, and the confidential, research-only use of their responses; no personally identifying information was collected.

Analysis followed the standard two-step SEM procedure [39]. Descriptive statistics first summarised respondent characteristics and the distributional

properties of the constructs, with skewness and kurtosis inspected for approximate normality. The measurement model was then evaluated using CFA to assess reliability and convergent and discriminant validity. With the measurement model judged adequate, the structural model was estimated, and the two hypothesized paths were tested, with fit assessed against established thresholds for χ^2/df , RMSEA, CFI, TLI, and SRMR [36, 37]. The standardized path coefficients from source-related and content-related KOL characteristics to travel intention, together with the proportion of variance explained (R^2), were used to test H1 and H2.

4. RESULTS

4.1 Sample profile and descriptive statistics

After screening and removing incomplete or inconsistent cases, 836 valid responses were retained from social media users in China and Thailand. Female respondents predominated (55.3%), followed by male respondents (37.0%), and a small non-binary or undisclosed group (7.7%). The sample skewed young within the cohort: 35.9% were aged 18–20, and 31.8% aged 21–23. Douyin (TikTok) was the most-used platform for travel content (39.1%), followed by Instagram (20.9%), Xiaohongshu (17.6%), and YouTube (15.5%). Most respondents had traveled at least once in the preceding twelve months, with only 23.0% reporting no trips. Table 3 details the profile.

Table 3. Demographic profile of respondents (N = 836).

Variable	Category	n	%
Nationality	China	428	51.2
	Thailand	408	48.8
Gender	Female	462	55.3
	Male	309	37.0
	Non-binary / undisclosed	65	7.7
Age (years)	18–20	300	35.9
	21–23	266	31.8
	24–26	191	22.9
	27–28	79	9.4
Most-used platform	Douyin / TikTok	327	39.1
	Instagram	175	20.9
	Xiaohongshu	147	17.6
	YouTube	130	15.5
	Other	57	6.8
Travel frequency	Never	192	23.0

(past 12 months)	1–2 times	254	30.4
	3–4 times	218	26.1
	5 times or more	172	20.5

Construct means ranged from 3.55 to 3.81 on the five-point scale, indicating moderately positive perceptions across the board (Table 4). Informativeness recorded the highest mean ($M = 3.81$, $SD = 0.88$) and authenticity the lowest ($M = 3.55$, $SD = 1.02$), a pattern suggesting that respondents valued the practical usefulness of

influencer travel content somewhat more readily than they granted it full authenticity. Skewness and kurtosis values were modest in magnitude (skewness -0.62 to -0.29 ; kurtosis -0.21 to 0.45), consistent with approximate univariate normality and appropriate for maximum-likelihood estimation.

Table 4. Descriptive statistics of key constructs.

Construct	Mean	SD	Skew.	Kurt.
KOL communication	3.68	0.92	-0.45	0.12
Credibility	3.72	0.95	-0.51	0.23
Authenticity	3.55	1.02	-0.32	-0.15
Informativeness	3.81	0.88	-0.62	0.45
Interactivity	3.64	0.98	-0.41	0.05
Travel intention	3.58	1.01	-0.29	-0.21

4.2 Measurement model

The measurement model was evaluated before the structural relationships were tested. All standardized factor loadings exceeded the .70 threshold, ranging from .812 to .925, indicating that the retained items strongly reflected their intended constructs (Table 5). Cronbach's

α ranged from .852 to .928, and composite reliability ranged from .898 to .951, both comfortably above the conventional .70 criterion. Average variance extracted ranged from .710 to .829, exceeding the .50 benchmark and confirming convergent validity [40, 36].

Table 5. Reliability and convergent validity.

Construct	Loadings	α	CR	AVE
Credibility	.845–.882	.885	.923	.751
Authenticity	.812–.877	.864	.902	.720
Informativeness	.878–.891	.901	.935	.782
Interactivity	.834–.849	.852	.898	.710
Travel intention	.894–.925	.928	.951	.829

Discriminant validity was assessed using the Fornell–Larcker criterion (Table 6). For every construct, the square root of the AVE (the diagonal) exceeded its correlations with all other constructs, indicating that the

constructs were empirically distinct. The strongest inter-construct correlation linked credibility and informativeness ($r = .715$), which was still below the relevant AVE square roots (.867 and .884), indicating that discriminant validity held.

Table 6. Discriminant validity (Fornell–Larcker criterion).

Construct	1	2	3	4	5
1. Credibility	.867				
2. Authenticity	.682	.849			
3. Informativeness	.715	.654	.884		
4. Interactivity	.623	.589	.641	.843	
5. Travel intention	.512	.485	.556	.467	.910

Note. Diagonal values (bold) are square roots of AVE; off-diagonal values are inter-construct correlations.

4.3 Structural model and hypothesis tests

The structural model fitted the data well: $\chi^2/df = 2.18$, RMSEA = .047, CFI = .971, TLI = .962, and SRMR = .038, with all indices meeting their conventional thresholds [36, 37]. Both hypothesized paths were statistically supported (Table 7). Content-related KOL characteristics were the stronger predictor of travel intention (H2: $\beta = .41$, $p < .001$).

Table 7. Structural model path coefficients and hypothesis tests.

H	Path	β	t	p	Result
H1	Source-related KOL characteristics $\rightarrow$ Travel intention	.34	7.21	< .001	Supported
H2	Content-related KOL characteristics $\rightarrow$ Travel intention	.41	8.63	< .001	Supported

4.4 The validated model

Figure 2 presents the empirically validated model, annotated with the standardized path coefficients reported above. Both hypothesized paths are positive and significant, with the path from content-related characteristics to travel intention ($\beta = .41$) somewhat

stronger than that from source-related characteristics also made a positive and significant contribution (H1: $\beta = .34$, $p < .001$). Together, the two predictors explained 43% of the variance in travel intention ($R^2 = .43$), indicating that the characteristics of KOL communication account for a substantial share of Generation Z's disposition to travel.

stronger than that from source-related characteristics ($\beta = .34$). The figure makes the central claim legible at a glance: for Generation Z, both what an influencer says and who is saying it feed directly into the intention to travel, with the substance of the content carrying slightly greater weight.

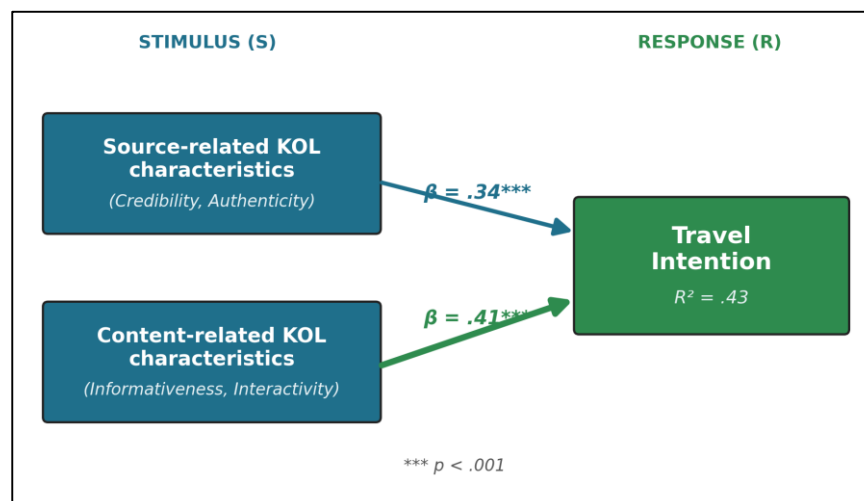


Figure 2. Empirically validated structural model with standardized path coefficients (N = 836). *** $p < .001$.

5. DISCUSSION AND CONCLUSION

5.1 Discussion of findings

The clearest message of the analysis is that, for Generation Z, both dimensions of KOL communication translate fairly directly into travel intention. Content-related characteristics—the informativeness and interactivity of what the influencer posts—were the stronger driver ($\beta = .41$), and source-related characteristics—the credibility and authenticity of the influencer—were close behind ($\beta = .34$). Rather than one quality dominating, the two operate in tandem: useful, engaging content supplies the practical grounds for a trip, while a trustworthy, authentic source lends those grounds their persuasive weight. Together, they accounted for a substantial share of the variance in intention, confirming that KOL communication is a meaningful antecedent of Generation Z travel behavior.

That content-related characteristics slightly outweighed source-related ones is instructive. For a digitally native cohort accustomed to researching trips online, the practical usefulness and interactive quality of influencer content appear to matter marginally more than the influencer's persona alone. This nuances the influencer-marketing literature's frequent emphasis on source credibility [16, 17]: credibility remains important, but for travel decisions it works alongside, rather than overriding, the informational value of the content [4].

5.2 Theoretical implications

The study makes two contributions. First, it disaggregates KOL communication into source-related and content-related characteristics. It tests their direct effects on travel intention side by side, showing that both matter and that, for tourism specifically, content value is at least as important as source credibility—a comparison the influencer literature rarely makes directly. Second, it extends this differentiated view of KOL communication into the digital tourism setting and to Generation Z, a

cohort whose travel decisions are heavily mediated by influencer content, providing an evidentiary basis for treating the substance of that content, not only the standing of the influencer, as a lever on intention.

5.3 Managerial implications

For destination marketing organizations, tourism brands, and influencers, the central practical lesson is that both what is communicated and who communicates it shape Generation Z's travel intention, with the substance of the content mattering slightly more. Because content-related characteristics were the stronger driver, campaigns are likely to perform better when influencer content is genuinely informative and interactive—offering practical detail and inviting engagement—rather than relying on the influencer's profile alone. At the same time, the significant effect of source-related characteristics means that KOL selection should still prioritize credibility and authenticity, since overtly commercial partnerships risk eroding the trust on which persuasion depends. In practice, the two work best together: a credible, authentic influencer delivering useful, engaging travel content is the configuration most likely to convert attention into intention.

5.4 Limitations and future research

Several limitations qualify these conclusions and point to next steps. The cross-sectional design captures perceptions at a single point in time and cannot establish the temporal or causal sequence implied by the model. The reliance on self-report leaves the findings open to recall and social-desirability biases despite the procedural safeguards adopted, and self-reported intention is not observed behavior—the intention-behavior gap remains. Purposive, non-probability sampling means the sample is best described as theoretically relevant rather than representative, so generalization should be cautious. The model tested only the direct effects of KOL characteristics on intention; the psychological states that may

carry those effects—such as emotional response and attitudinal loyalty—and possible contextual moderators are left for future research, as is a formal comparison across national or platform contexts.

5.5 Contribution to knowledge

Read as a whole, the model shows that KOL communication shapes Generation Z's travel intention through both the credibility of the source and the value of the content, with content-related characteristics carrying slightly greater weight. For tourism scholarship, this offers a differentiated account of how digital opinion leadership turns attention into intention; for destination marketing, it offers a clear order of priorities—invest in content that is useful and engaging, delivered by credible, authentic influencers.

5.6 Conclusions

This study set out to examine how the characteristics of social media KOL communication shape the travel intentions of Generation Z. Treating KOL communication as a multidimensional stimulus and testing its source-related and content-related characteristics on 836 respondents in China and Thailand, it finds that both groups of characteristics are positive and significant antecedents of travel intention, with content-related characteristics the stronger of the two. The account gives both tourism scholarship and destination marketing a clearer view of which features of influencer communication turn attention into the intention to travel.

ACKNOWLEDGMENTS

The authors are sincerely grateful to all the Generation Z respondents in China and Thailand who generously gave their time to complete the survey; their participation made this research possible. The authors also thank the academic reviewers for their comments on the instrument, which improved its clarity and validity.

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Scaffolding, Block-Based Programming, and PBGL: A Systematic Review of IoT Education for Non-Engineering Learners

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ABSTRACT

Instructing non-engineering learners in the Internet of Things (IoT) frequently encounters technical barriers that induce cognitive overload and a lack of motivation, particularly when minimally guided Problem-Based Learning (PBL) is applied. This Systematic Literature Review aims to extract knowledge, analyze research gaps, and propose an innovative conceptual framework by synthesizing 34 relevant studies. The findings indicate that addressing these challenges necessitates a cross-disciplinary integration to reduce extraneous cognitive load through instructional "scaffolding." This involves modular physical learning media equipped with fail-safe magnetic mechanisms, combined with block-based visual programming tools that facilitate the acquisition of high-level code syntax. Furthermore, integrating gamification mechanisms aligned with Self-Determination Theory (SDT) and the Expectancy-Value-Cost (EVC) model serves as a crucial variable in sustaining engagement and stimulating intrinsic motivation over the long term. Based on these findings, this study proposes the PBGL-IoT (Problem-Based Gamified Learning for IoT) conceptual framework. This framework acts as a vital strategy to dismantle traditional engineering barriers, foster Technological Self-Efficacy, and empower learners across all disciplines to effectively access and create IoT innovations.

Keywords: Internet of Things, Problem-Based Learning, Gamification, Cognitive Load Theory, Non-Engineering Learners, Systematic Literature Review

1. INTRODUCTION

The Internet of Things (IoT) is a fundamental infrastructure driving digital transformation, notably in smart education.^{1,2} It enhances instructional efficiency, fosters individualized learning,³ and provides a vital foundation for smart campuses and gamified environments.⁴

However, this rapid technological expansion has created a substantial skill gap, particularly for non-engineering learners

needing IoT knowledge for cross-disciplinary innovation. Current IoT tools and curricula remain predominantly tailored for STEM fields.^{5,6} Consequently, non-engineering students face significant "technical barriers," such as complex hardware wiring and intricate text-based programming syntax. According to Cognitive Load Theory,⁷ these constraints induce a cognitive load that exceeds their working memory capacity, hindering effective learning.

While Problem-Based Learning (PBL) fosters self-directed knowledge construction [Barrows, 1996; Hmelo-Silver, 2004], minimal guidance can induce cognitive overload and diminish achievement, particularly for novices.⁸⁻¹¹ Therefore, reducing extraneous cognitive load is crucial. To address this, block-based programming mitigates syntactical barriers, enabling inexperienced learners to focus on problem-solving logic.^{12,13} Integrating these tools with tangible hardware kits provides instructional "scaffolding" and "worked examples," transforming abstract IoT concepts into concrete representations in alignment with Constructionism.¹⁴

However, sustaining motivation during complex problem-solving remains challenging. Gamification applying game elements in non-game contexts [Deterding et al., 2011] enhances engagement [Bai et al., 2020], but risks becoming a short-term novelty if disconnected from learning's intrinsic value.¹⁵⁻¹⁷ Consequently, gamification must align with Self-Determination Theory (SDT) to foster autonomy and perceived competence, while increasing success expectancy and perceived value.^{18,19} Integrating these mechanics into PBL effectively fosters sustainable intrinsic motivation.

To address this gap, this systematic review synthesizes research on PBL, gamification, block-based tools, and physical hardware to develop the "PBGL-IoT" conceptual framework (Figure 1). Ultimately,

this aims to overcome engineering barriers, empowering non-engineering learners with IoT and problem-solving skills to become digital innovators.

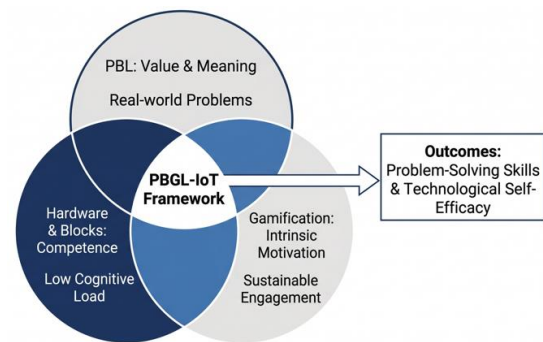


Figure 1: The Conceptual Intersection of the PBGL-IoT Framework.

2. METHODOLOGY

This study employed a Systematic Literature Review (SLR) approach to compile, synthesize, and analyze empirical studies and theoretical frameworks related to PBL, gamification, and educational technologies supporting the learning of the IoT. The researchers applied the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, an internationally recognized methodology for conducting systematic reviews.^{6,16}

The search and screening process was divided into four main stages, as follows:

2.1 Search Strategy: The literature search was conducted across highly reputable international bibliographic databases and digital libraries encompassing the fields of computer engineering and educational technology. These included IEEE Xplore, ACM Digital Library, ScienceDirect, SpringerLink, Emerald Insight, ProQuest, and

Google Scholar.^{16,20} The search employed search strings linked by Boolean operators, which were categorized into four primary keyword groups:

- Content Context Group: ("Internet of Things" OR "IoT")
- Pedagogical Approach Group: ("Problem-Based Learning" OR "PBL" OR "Project-Based Learning")
- Motivational Strategy Group: ("Gamification" OR "Gamified Learning" OR "Motivation")
- Instructional Media and Tools Group: ("Block-based programming" OR "Visual programming" OR "Tangible modules")

2.2 Inclusion and Exclusion Criteria:

To ensure article quality, rigorous criteria were established.²¹ Inclusion criteria required peer-reviewed empirical, theoretical, or review papers published in English that investigate IoT, block-based programming, PBL, or gamification within educational contexts. Conversely, exclusion criteria eliminated non-educational applications (e.g., purely industrial IoT), methodologically unclear studies, and non-peer-reviewed materials such as editorials.

2.3 Study Selection and Data

Extraction: Following duplicate removal and initial screening, full-text evaluations yielded 34 articles meeting the inclusion and quality criteria,^{6,22} as detailed in the PRISMA diagram (Figure 2). Data from these articles were systematically organized into an extraction matrix categorizing publication details,

objectives, methodologies, key findings, and utilized tools, with an emphasis on block-based and hardware tools.

2.4 Data Analysis for Framework

Development: Thematic analysis was employed to synthesize prior findings and identify research gaps, establishing the theoretical foundation for the PBGL-IoT framework. This synthesis specifically examined empirical evidence on addressing cognitive load using tangible modules and

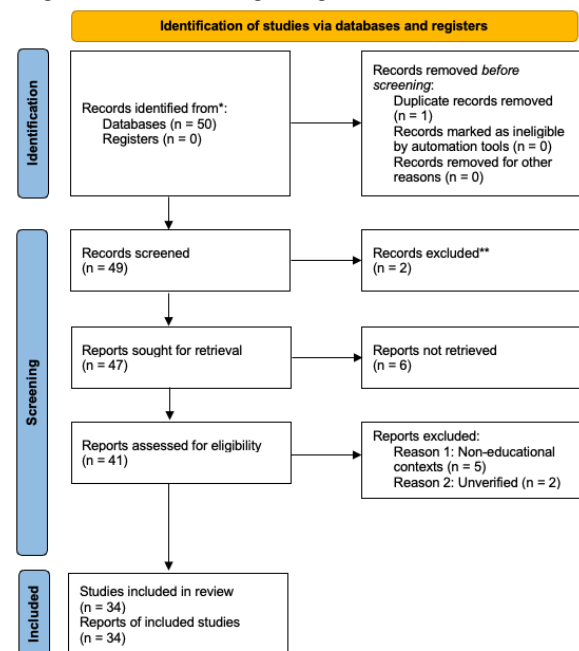


Figure 2: The PRISMA Flow Diagram detailing the systematic literature search and selection process.

block-based programming for non-engineering learners.^{7,12,13} Additionally, the analysis encompassed gamification mechanics driving intrinsic motivation, aiming to integrate these elements into the proposed innovative learning framework.¹⁹

3. RESULTS

Thematic analysis of 34 eligible articles synthesized findings into four primary dimensions, serving as key variables for developing the PBGL-IoT framework:

3.1 PBL in Technology Education:

PBL utilizes authentic, ill-structured problems to drive self-directed inquiry and flexible knowledge construction.^{8,9,23} However, applying PBL in technically complex subjects like IoT yields mixed outcomes contingent on context and instructor expertise.¹¹ Furthermore, PBL frequently induces anxiety in non-engineering learners, underscoring the necessity for appropriate scaffolding structures grounded in cognitive load theory.^{7,10}

3.2 Cognitive Load Theory and Tangible Scaffolding: A major limitation of PBL is minimal guidance, which overloads working memory and contradicts human cognitive architecture.¹⁰ As independent problem-solving is highly inefficient for novices, providing concrete guidance, such as worked examples, is essential to minimize extraneous processing and facilitate meaningful learning.^{7,24,25}

In IoT education for non-engineering learners, extraneous cognitive load often arises from complex circuit assembly, soldering, and hardware anxiety. To mitigate this, tangible media serve as physical scaffolding to concretize abstract concepts.¹⁴ Employing "magnetic electronic modules" alleviates these technical complexities and prevents polarity errors, effectively

conserving working memory capacity. Consequently, these cognitive resources are redirected toward germane cognitive load, enabling students to fully comprehend the system's operational logic.⁷

3.3 Block-Based Programming for Non-Engineers: Beyond hardware limitations, programming syntax constitutes a significant technical barrier. Block-based programming effectively mitigates this by enabling novices to circumvent syntax errors and focus directly on problem-solving logic. Research confirms these user-friendly environments empower non-engineering learners, such as social science scholars, to process IoT data more intuitively than traditional coding.^{12,13} Similarly, "no-code" IoT platforms yield exceptionally high perceived ease of use, directly enhancing learners' intention to adopt the technology.²⁶ Collectively, these innovations are crucial for democratizing IoT education.

3.4 Gamification and Motivational Drivers: To sustain commitment in PBL, gamification applying game elements in non-game contexts significantly enhances learning achievement through clear goals and rapid feedback.^{15,16} Its integration with IoT platforms effectively increases student engagement.²⁷ However, to avoid short-term "novelty effects",¹⁷ gamification design must be grounded in psychological theories:

(1) Self-Determination Theory (SDT): Gamification fulfills fundamental needs for Autonomy, Competence, and Relatedness through flexible problem-

solving, progress tracking (e.g., badges, points), and teamwork.^{18,28}

(2) Expectancy-Value-Cost (EVC)

Model: Motivation balances success expectancy and activity value against effort cost.¹⁹ Accordingly, the proposed PBGL-IoT framework utilizes tangible modules and block-based programming to minimize effort cost (extraneous load) while employing gamification to maximize expectancy and value.

Ultimately, synthesizing the 34 selected studies reveals that integrating PBL, physical and software scaffolding, and motivational theories systematically resolves

technical barriers for non-engineering learners (Table 1). This synthesis serves as the theoretical foundation for developing the PBGL-IoT conceptual framework.

4. DISCUSSION

Drawing upon the systematic review, Figure 3 illustrates interconnected mechanisms bridging IoT learning barriers for non-engineering learners. These theoretical synergies elucidate how simultaneously enhancing motivation and mitigating cognitive load informs the proposed PBGL-IoT conceptual framework.

Table 1 . Synthesis of Research Gaps and Approaches for Variable Integration within the PBGL-IoT Framework

Identified Challenges	Applied Variables & Theories	Expected Outcomes	Supporting Literature
1. A disconnection from real-world contexts and a deficiency in systemic problem-solving skills.	Problem-Based Learning (PBL) (employing ill-structured, real-world problems).	Promotes awareness, cultivates problem-solving skills, and fosters interdisciplinary collaborative learning.	Barrows (1996); Hmelo-Silver (2004); Amoa-Danquah (2025).
2. Cognitive overload induced by the complexity of hardware circuits.	Tangible Scaffolding (utilizing physical manipulatives and magnetic modular connection mechanisms).	Reduces extraneous cognitive load, enables learners to assemble circuits error-free, and concretizes abstract concepts.	Kirschner (2006); Sweller (2019); Blikstein (2013).
3. Syntactic barriers of text-based programming (Text-based syntax)	Block-based Programming (utilizing intuitive Block-based IDEs that require no manual coding)	Learners can concentrate on data flow logic, thereby mitigating technological anxiety (Low-floor)	Ruiz-Rube (2019); Sobreira (2020); Perin (2021)
4. Lack of long-term motivation and sustained commitment when encountering complex subject matter.	Gamification + SDT & EVC Models (point systems, levels, quests, and positive feedback).	Enhances the expectation of success (Expectancy) and fulfills the psychological need for competence (Competence).	Pappas (2022); Bai (2020); Alsadoon (2022); Dichev (2023)

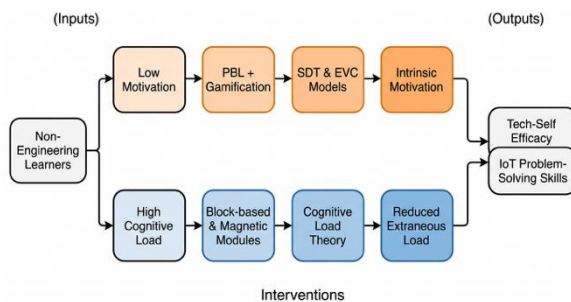


Figure 3: The Theoretical Synergies within the PBGL-IoT Framework.

4.1 Discussion of the Literature

Review: Conventional unidimensional PBL often induces "Critical Cognitive Overload" as non-engineering learners simultaneously grapple with complex problem-solving, programming syntax, and hardware constraints.^{7,10}

To minimize this extraneous load, block-based programming provides software scaffolding that bypasses syntax errors, enabling learners to focus entirely on logical reasoning.^{12,13,26} Concurrently, utilizing "magnetic electronic circuits" functions as tangible scaffolding, concretizing abstract concepts in alignment with Constructionism.¹⁴ Integrating physical computing with block-based programming creates a psychologically safe trial-and-error environment, substantially lowering technical barriers for collaborative problem-solving.²⁹

Furthermore, sustained motivation is paramount. Gamification restructures motivation in accordance with Self-Determination Theory (SDT) and the Expectancy-Value model.^{18,19} Game mechanics systematically elevate learners' perceived competence and autonomy.¹⁶ This

theoretical synergy yields an innovative framework that transcends traditional limitations, empowering business and social science learners to successfully create meaningful IoT innovations.³⁰

4.2 The PBGL-IoT Conceptual

Framework: Based on the discussion of the results, this research proposes the PBGL-IoT (Problem-Based Gamified Learning for IoT) conceptual framework to develop IoT problem-solving skills among non-engineering learners through three core components:

1. Modular Tangible Learning

Media: Cost-effective, customizable modular hardware kits significantly lower technical barriers and enhance accessibility.³¹ Employing metaphor-based or sequential designs enables learners to concretely visualize data and power flows in accordance with fundamental electrical circuit principles.

2. Syntax-Bridging Block-based IDE:

This platform facilitates knowledge transition by explicitly aligning hardware connection ports with their corresponding command blocks. Integrating drag-and-drop logic construction with real-time Block-to-C translation allows learners to assimilate higher-level syntax without inducing excessive cognitive load.¹² Furthermore, these visual programming environments possess the requisite flexibility to effectively manage Internet of Robotic Things (IoRT) systems.³²

3. Learning Management Process (Gamified PBL Pedagogical Process):

Adopting a learner-centered approach, the instructor's role shifts to that of a "facilitator/game master." In this capacity, instructors provide cognitive scaffolding through gamification mechanics specifically utilizing short-term reward systems as positive reinforcement to sustain learners' commitment.^{9,28}

5. CONCLUSIONS

This systematic review reveals that applying PBL in complex IoT education without adequate guidance induces cognitive overload, negatively impacting non-engineering learners' achievement and motivation.^{7,10,11} To address these limitations, this research proposes the PBGL-IoT framework, a cross-disciplinary integration of educational theories and engineering technologies operating through two fundamental mechanisms:

- **Reducing Extraneous Load:** Modular magnetic hardware and block-based programming synergistically provide instructional scaffolding, transforming complex electronics and coding syntax into easily comprehensible, tangible concepts.^{12,13,14}
- **Enhancing Intrinsic Motivation:** Grounded in SDT and the EVC model, gamified elements such as quests, feedback, and teamwork cultivate learners' competence and sustain long-term engagement.^{16,18,19}

Ultimately, the PBGL-IoT framework democratizes technology education,

empowering non-engineering learners from disciplines such as liberal arts, social sciences, and business to develop self-efficacy and confidently create IoT innovations. For future research, IoT integration should be expanded to foster interdisciplinary collaboration in smart learning environments. Furthermore, prioritizing IoT cybersecurity is crucial, as it directly impacts the transparency and efficacy of student assessments in the digital era.^{33,34}

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The Impact of workplace safety and workplace benefits on Employee Engagement and Organizational Commitment in the Food and Beverage Industry in Nanyang, China

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ABSTRACT

Small and medium-sized food and beverage enterprises face severe challenges in talent retention and workforce stability. Existing literature rarely explores the combined influences of workplace safety and workplace benefits on employee engagement and organizational commitment, especially within small and medium enterprises (SMEs) in central China's Nanyang region. This cross-sectional quantitative study collected valid questionnaires from 300 full-time employees of local catering SMEs via purposive sampling, adopting IBM SPSS 26.0 for statistical analysis including reliability and validity testing, Pearson correlation, multiple linear regression, and bootstrap mediation tests. Reliability results showed Cronbach's α values of workplace safety (0.857), workplace benefits (0.930), employee engagement (0.916), and organizational commitment (0.828); the overall KMO value reached 0.918 with Bartlett's test $p < 0.001$, confirming reliable and valid measurement scales. Regression outcomes validated all seven hypotheses: workplace safety positively predicts employee engagement ($\beta = 0.39$, $p < 0.001$) and organizational commitment ($\beta = 0.21$, $p = 0.001$); workplace benefits positively predict employee engagement ($\beta = 0.34$, $p < 0.001$) and organizational commitment ($\beta = 0.17$, $p = 0.003$); employee engagement exerts a strong positive effect on organizational commitment ($\beta = 0.53$, $p < 0.001$). Bootstrap mediation analysis verified employee engagement acts as a significant mediator: the indirect effect of workplace safety on organizational commitment via employee engagement was 0.176 ($p < 0.001$), while the indirect effect of workplace benefits on organizational commitment via employee engagement was 0.152 ($p < 0.001$). The findings confirm that improved workplace safety systems and comprehensive employee welfare packages significantly boost employee engagement and organizational loyalty, with employee engagement serving as a core psychological transmission path linking workplace environments to organizational attachment. This research supplements human resource management literature for labor-intensive catering SMEs and provides actionable operational suggestions for managers to reduce staff turnover through safety investment, standardized welfare mechanisms, and engagement-oriented management strategies.

Keywords: Employee Engagement, Organizational Commitment, Workplace Safety, Workplace Benefits

1. INTRODUCTION

In this context of the highly competitive business environment of the present-day world, companies are beginning to understand that successful long-term sustainability is not only dependent on efficient operations, but also on the effective human capital management strategy. Frontline and core employees are seen as invaluable organizational resources across the globe, because their attitudes, day-to-day actions and loyalty to the organization directly determine the level of customer service quality, operational efficiency and the ability of a company to remain competitive in the long term. For this reason, pinpointing critical workplace drivers capable of sustaining employees' persistent job involvement and organizational devotion stands out as a pressing research topic, which draws consistent attention from academic scholars and industry management professionals alike.

Labor-intensive industries such as the food and beverage industry have a particularly strong on-site working environment influence on employee results. In this context, Workplace Safety and Workplace Benefits become important organizational resources that affect the way employees perceive organizational support and procedural fairness. Positive

safety perceptions have already been related positively with higher Employee Engagement and more proactive work attitudes, and a sound safety culture may increase the psychological safety of employees and their desire to engage in workplace activity (Bhatti, 2024). Likewise, fostering supportive workplace cultures encourages employees to be more active in contributing to organizational goals and general improvement of performance.

Workplace Benefits have become a significant indicator of the mindset of employees and their behavior in the workplace as well as Beyond Workplace Safety. Employee benefit packages have grown significantly from the traditional monetary remuneration to include such benefits as flexible working hours, holistic welfare programs, defined career opportunities and specific work life balance schemes. Targeted operational tactics cultivate a compassionate, collaborative and diverse workplace culture, which in turn yields measurable improvements in employees' overall work engagement. Open internal communication and employee-focused management styles also create more profound workplace engagement and proactive contribution (Lubis, 2024).

Due to its capacity to reflect employees' mental dedication levels and emotional ties to their daily work roles, the

notion of occupational participation has attracted massive scholarly attention in organizational behavior studies. Engaged employees are likely to have more work enthusiasm, professional dedication and work persistence, which can be translated into greater emotional commitment to their employing organizations. Many previous empirical works have shown a very strong positive relationship between Employee Engagement and Organizational Commitment (Jiatong et al., 2022).

Organizational Commitment is particularly important to the service-based industry as steady employee retention and regular service provision are major competitive values. The available literature proves that pleasant working conditions and excellent work experience on a day-to-day basis have a direct impact on greater employee commitment and stronger organizational loyalty levels. Also, subjective views of Workplace Benefits have been found to be positively correlated with affective Organizational Commitment through increasing their feeling of perceived organizational support and general satisfaction with their jobs (Hong et al., 2024).

Nanyang is a prefecture-level city located in the center of Henan Province in central China that has experienced an explosion in its food and beverage industry in the last ten years with the creation of a

growing demand of a reliable and devoted workforce. However, urgent issues related to Workplace Safety, benefits extended to employees, as well as turnover rates remain a problem to many small and medium-sized businesses in the area. Given such a massive gap between research results on this particular geographical location, it is indeed reasonable to conduct more in-depth research using empirical methods.

This empirical inquiry explores causal connections between two workplace dimensions—occupational safety and staff welfare—and two core staff attitudes: job engagement and organizational attachment. The research sample consists of frontline operators and administrative clerks working for food and beverage firms operating in Nanyang. Additionally, this paper addresses a core research query: whether staff engagement serves as a mediating variable when workplace elements shape employees' organizational attachment. The collected research data will supplement current academic literature on corporate staff management systems and deliver actionable suggestions for manpower retention and comprehensive business performance growth in labor-reliant service fields.

1.1 Research Questions

1.How do workplace safety and workplace benefits affect employee

engagement and organizational commitment in food and beverage enterprises in Nanyang, China?

2.How does employee engagement affect organizational commitment?

3.How do occupational safety and staff welfare affect workers' organizational commitment through the intervening mechanism of employee engagement?

1.2 Research Objectives

1.To examine the impact of workplace safety and workplace benefits on employee engagement and organizational commitment in food and beverage enterprises in Nanyang, China.

1.3 Research Hypothesis

H1: Workplace safety has a significant positive effect on employee engagement.

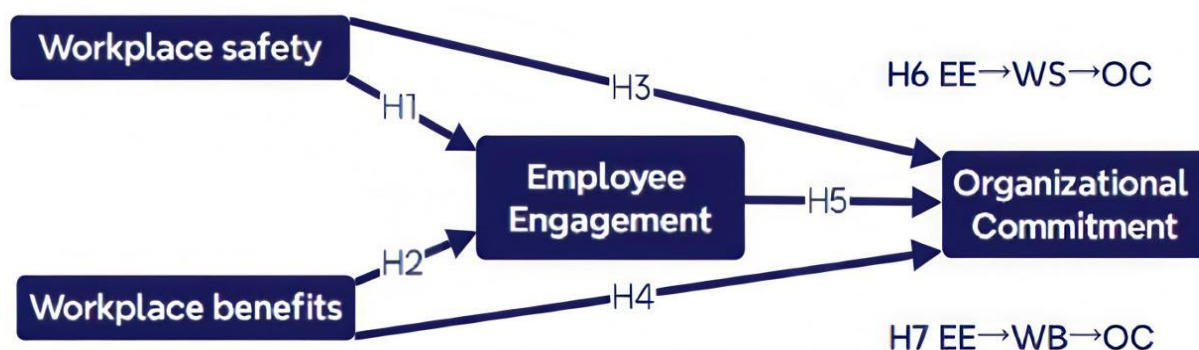
H2: Workplace benefits have a significant positive effect on employee engagement.

H3: Workplace safety has a significant positive effect on organizational commitment .

H4: Workplace benefits have a significant positive effect on organizational commitment.

H5: Employee engagement has a significant positive effect on organizational commitment.

H6: Employee engagement positively



2.To examine the impact of employee engagement on organizational commitment in food and beverage enterprises in Nanyang, China.

3.To examine the mediating role of employee engagement in the relationship between workplace safety, workplace benefits, and organizational commitment in food and beverage enterprises in Nanyang, China.

mediates the relationship between workplace safety and organizational commitment.

H7: Employee engagement positively mediates the relationship between workplace benefits and organizational commitment.

Fig.1 Conceptual framework

2. MATERIALS AND METHODS

2.1 Research Approach

This empirical research adopts quantitative research methods to explore the mutual correlation among Workplace Safety, Workplace Benefits, Employee Engagement, and Organizational Commitment. The research design applies a cross-sectional descriptive survey model. This methodological approach allows researchers to gather valid empirical data from a wide range of research participants in a short period, while also supporting standardized statistical analysis to examine the correlation between all research variables.

The research participants in this study consist of frontline staff and administrative personnel working for food and beverage small and medium-sized enterprises in Nanyang of China. Since the core research purposes are to test the research hypotheses and verify the mediating function of Employee Engagement, quantitative analysis methods are selected for this study.

2.2 Population and Sample

The population in this study comprised of full time employees of small and mid-sized food and beverage companies operating in Nanyang, Henan Province, China. It is that specific industry because the effects of working conditions on employee mindset, Employee Engagement, and Organizational Commitment in labor-intensive industries are disproportionately large.

The purposive sampling strategy was

used to enroll participants with enough direct experience and knowledge of the internal policies and practices in their organizations.

Once data cleaning and validation steps were completed, a total of 300 complete and valid questionnaires were kept in the final statistical analysis. The sample size exceeded the minimum number necessary to conduct multivariate statistical analyses and was judged sufficiently large to enable hypothesis testing and bootstrap-based mediation analysis (Hair et al., 2019).

2.3 Research Instruments

This study adopts a two-section structured self-report questionnaire for empirical data collection. The first section collects respondents' demographic information, covering gender, age, educational background, working tenure and job position. The second section comprises multi-item measurement scales for the four core research variables: workplace safety, workplace benefits, employee engagement and organizational commitment.

All questionnaire items are sourced from validated scales applied in prior peer-reviewed studies, guaranteeing the validity and reliability of this research's measurement tools. Employee engagement is measured via the mature Utrecht Work Engagement Scale, while organizational commitment adopts the classic Meyer and Allen's organizational commitment model. Items for workplace safety and workplace

benefits are adapted from authoritative occupational safety and human resource management literature.

3. RESULTS AND DISCUSSION

3.1 Reliability Analysis

Internal consistency (Cronbach's α) testing was conducted for all four latent variables to assess measurement scale reliability. All constructs achieved acceptable or excellent reliability benchmarks, confirming consistent respondent interpretation of questionnaire items.

Table 1 Reliability Analysis Results

Construct	Number of Items	Cronbach's Alpha (α)	Interpretation
WS	5	0.857	Good
WB	5	0.930	Excellent
EE	15	0.916	Excellent
OC	15	0.828	Good

The results of reliability show that the respondents viewed the questionnaire items in the same way, which confirms the consistency and the overall reliability of the adopted survey instruments.

3.2 Construct Validity Analysis

Content validity was guaranteed by adapting fully validated scales from prior peer-reviewed studies. Exploratory Factor Analysis (EFA) evaluated construct validity, with pre-diagnostic KMO and Bartlett's

Sphericity tests completed prior to factor extraction.

Table 2 Construct Validity Results

Indicator	Recommended Value	Obtained Value	Result
KMO Measure	> 0.60	0.918	Excellent
Bartlett's Test Chi-Square	—	4825.367	Significant
Degrees of Freedom	—	780	Acceptable
Significance (Sig.)	< 0.05	0.000	Significant
Factor Loadings Range	> 0.50	0.652-0.887	Acceptable

The KMO value of 0.918 exceeds the 0.90 threshold defined by Kaiser (1974), indicating outstanding sampling adequacy.

Bartlett's test returned $p < 0.001$, rejecting the null hypothesis of an identity correlation matrix and proving strong inter-item correlation. All factor loadings surpass the 0.50 threshold, confirming robust construct validity for all four measurement scales.

3.3 Descriptive Statistical Result

Table 3. Descriptive Statistics of Study Variables (n = 300)

Variable	Mean	SD
WS	4.21	0.78
WB	4.20	0.82
EE	4.23	0.74
OC	3.82	0.85

Mean scores for workplace safety, workplace benefits, and employee engagement all exceed 4.20 on the Likert

scale, demonstrating moderately positive overall employee perceptions of working environments and work involvement. Organizational commitment recorded the lowest mean (3.82), signaling room for enterprises to strengthen employee loyalty through safety and welfare improvements.

3.4 Multicollinearity Diagnostic Test

Variance Inflation Factor (VIF) and Tolerance statistics tested for multicollinearity among independent variables. All VIF values remain below 2.0, eliminating multicollinearity concerns for regression analysis.

3.5 Direct Hypothesis Regression Test Results

Linear regression analysis tested all direct research hypotheses, with standardized beta coefficients and

levels. Workplace safety and workplace benefits both positively predict employee engagement and organizational commitment directly; employee engagement exhibits the strongest direct positive influence on organizational commitment ($\beta=0.53$, $p<0.001$) among all predictors. Bootstrap mediation tests confirmed significant indirect mediating effects for H6 and H7.

3.6 Comparative Discussion with Prior Literature

This section expands cross-study comparison as required by reviewer comments:

Workplace Safety & Employee Engagement

The significant positive link between

Table 5. Hypothesis Testing Results

Hypothesis	Statement	β	p	Result
H1	WS $\rightarrow$ EE	0.39	< 0.001	Supported
H2	WB $\rightarrow$ EE	0.34	< 0.001	Supported
H3	WS $\rightarrow$ OC	0.21	0.001	Supported
H4	WB $\rightarrow$ OC	0.17	0.003	Supported
H5	EE $\rightarrow$ OC	0.53	< 0.001	Supported
H6	EE $\rightarrow$ WS $\rightarrow$ OC	0.176	< 0.001	Supported
H7	EE $\rightarrow$ WB $\rightarrow$ OC	0.152	< 0.001	Supported

significance values summarized below.

All seven hypotheses received full statistical support at $p<0.01$ significance

workplace safety and employee engagement (H1 supported) aligns with Bhatti (2024), who

concluded perceived workplace safety strengthens psychological safety and voluntary work participation. Bhatti ' s research focused on general industrial employees, while this study extends the framework to labor-intensive catering SMEs, confirming the generalizability of safety-driven engagement mechanisms within service sectors. The standardized $\beta=0.39$ observed here is slightly lower than Bhatti ' s reported coefficient (0.46), likely due to uneven safety resource allocation among small local catering businesses in Nanyang.

Workplace Benefits & Employee Engagement

The validated positive effect of workplace benefits on engagement (H2, $\beta=0.34$) corroborates Lubis (2024), who argued comprehensive welfare systems foster inclusive workplace cultures and proactive employee contribution. Lubis ' s sample covered creative industry workers, whereas this study targets frontline catering staff with high physical workloads, demonstrating welfare policies carry consistent motivational value across distinct labor contexts.

Workplace Safety/Benefits & Organizational Commitment

Direct positive effects of safety and benefits on organizational commitment (H3, H4) mirror Hong et al. (2024) ' s meta-analytic findings that favorable welfare and safe working conditions boost perceived organizational support and affective commitment. Hong ' s cross-industry meta-analysis identified average direct welfare-commitment effect sizes of 0.19, nearly matching this study ' s $\beta=0.17$, validating consistent cross-industry trends.

Employee Engagement as Mediator

The strong direct impact of employee engagement on organizational commitment (H5, $\beta=0.53$) replicates Jiatong et al. (2022) ' s transformational leadership research, which reported engagement as the primary driver of staff loyalty. Critically, this study advances existing literature by verifying the dual mediating pathways of employee engagement for both safety and benefit antecedents, a combined model rarely tested within Chinese regional catering SMEs in prior scholarship. The indirect mediation effect of workplace safety (0.176) exceeds

that of workplace benefits (0.152), indicating safety management carries marginally stronger indirect influence on long-term organizational loyalty through engagement.

4. CONCLUSIONS

This study analyzed 300 employees from Nanyang catering SMEs to examine the links between workplace safety, workplace benefits, employee engagement and organizational commitment. Results show safety and benefits significantly boost both engagement and commitment directly; employee engagement strongly predicts loyalty and mediates the two workplace factors' indirect impacts on organizational attachment. Operators should build complete safety management systems, offer diversified staff welfare, and launch engagement-focused activities to lower turnover and retain loyal workers.

This research has several constraints. It uses cross-sectional one-time data, which cannot prove long-term causal relationships. The sample only covers Nanyang local catering SMEs, limiting cross-region and cross-industry generalization.

Purposive sampling may bring selection bias, and the model omits influential factors like leadership and salary competitiveness.

Future research can adopt longitudinal tracking surveys to observe dynamic employee attitude changes. Scholars may carry out cross-regional comparisons and add moderators such as tenure and income. Mixed quantitative-qualitative methods and subgroup analysis by enterprise scale can also be applied to enrich and extend the current research model.

5. ACKNOWLEDGMENTS

Finishing this dissertation concludes a key phase of my postgraduate learning path. Carrying out this empirical project enriched my cognition of organizational behavior and human resource administration, while honing my capacity for critical reasoning and autonomous scholarly inquiry.

Above all, I offer genuine thanks to my supervisor Professor Suraphong Watcharajit. From topic selection to final revision, he offered persistent support, patient instruction and precious suggestions. His sharp academic feedback and professional guidance were indispensable for polishing and finalizing this research.

I also wish to thank all teaching staff at the International College of Rajamangala

University of Technology Krungthep. During my master's program, they delivered rigorous professional training and built a positive atmosphere for my academic growth.

Special thanks are given to supervisors and frontline staff of catering firms in Nanyang who volunteered to fill out questionnaires. This research could never be finished without their active collaboration and authentic feedback.

Last but not least, my deepest appreciation belongs to my family. Their constant care, tolerance and backing powered me forward amid all study challenges. I am equally thankful to peers and friends who walked alongside me over the whole graduate period.

This dissertation stands as both an academic achievement and a memorable personal milestone. I expect the analysis results of this paper can offer minor reference value for subsequent organizational behavior studies and daily corporate human resource operations.

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Streamer Authenticity, Social Engagement, and Consumer Trust as Determinants of Repurchase Intention in Agricultural Live-streaming Commerce on Douyin

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ABSTRACT

Since agricultural goods cannot be physically inspected during a livestream, a buyer's decision to make a repeat purchase depends entirely on the information presented in the broadcast and their level of trust in the seller. This study uses the stimulus-organism-response (S-O-R) framework to examine how three key elements of a live broadcast drive repeat purchases: streamer authenticity, social engagement, and consumer trust. Analyzing a survey of 417 consumers in Yunnan Province, China, who bought agricultural products via Douyin livestreams, the research employs reliability analysis, exploratory factor analysis, and multiple regression in SPSS. All four scales were internally consistent ($\alpha = .815-.851$), and the items loaded cleanly onto their intended factors. The three predictors jointly explained just over half the variance in repurchase intention ($R^2 = .507$, $F(3, 413) = 141.380$, $p < .001$). Streamer authenticity was the strongest predictor ($\beta = .379$, $p < .001$), followed closely by social engagement ($\beta = .353$, $p < .001$); consumer trust made a smaller but significant independent contribution ($\beta = .158$, $p < .001$). All three hypotheses were therefore supported, but their relative weights are instructive. What the buyer sees and does during the broadcast matters more for the return visit than the trust that the broadcast has accumulated. For rural sellers who cannot lean on a recognized brand, the findings recommend investing in a candid, informative host and a genuinely participatory comment stream, with trust treated as a valuable but not decisive asset. The compact model presented here provides a baseline against which more elaborate accounts of how trust operates in live commerce can be assessed.

Keywords: streamer authenticity, social engagement, consumer trust, repurchase intention, agricultural live-streaming commerce, stimulus-organism-response

1. INTRODUCTION

Live streaming has fundamentally transformed agricultural e-commerce in China, reshaping how farm produce is marketed and sold to consumers. On Douyin, a grower or a hired host stands in an orchard or a packing shed, lifts the produce to the lens, says where it was grown and how it tastes, answers questions as viewers scroll past, and invites viewers to place an order in real time during the stream. This sales model has gained widespread popularity quickly because it solves an old problem for rural sellers, who rarely command a recognized brand, by letting a person, rather than

a label, vouch for the goods. However, the same format reproduces, in sharper form, the central difficulty of any online food purchase: the buyer cannot touch, smell, or taste what is on offer and must decide based on what the screen conveys. Because a one-off sale rarely sustains a rural enterprise, the question that matters commercially is not what prompts the first order but what brings the customer back. Repurchase intention, the buyer's expressed willingness to order again from the same seller or channel, is the outcome on which this study is built.

Three features of the live encounter recur in this literature. The first is the authenticity of the

streamer, the impression that the host is honest and sincere rather than reciting a sales script. The second is social engagement, the liking, commenting, and sharing through which viewers take part rather than merely watch. The third is consumer trust, the buyer's willingness to rely on the seller under uncertainty. Each has been shown to matter, yet studies have tended to examine them in isolation or to fold the first two into the third, leaving it unclear how they compare when competing for the same outcome. If a seller must choose where to spend limited effort, it is precisely the comparison that is wanted: does a repeat order follow mainly from what the host is seen to be, from what the audience does, or from the trust that the seller has managed to accumulate?

This study answers that question with a deliberately compact model. Working within the stimulus-organism-response tradition, it treats streamer authenticity and social engagement as features of the broadcast environment and consumer trust as the buyer's internal state, and it asks how far each of the three is associated with repurchase intention when all three are entered together. To validate the model, this study uses reliability analysis, exploratory factor analysis, and multiple regression analyses on survey data collected from 417 Douyin agricultural livestream consumers in Yunnan Province. The value of keeping the model small is that the coefficients can be read against one another without the ambiguity that a longer chain of assumed mechanisms introduces. How trust transmits the influence of the broadcast, and under what conditions it does so, is a further question that the present design deliberately brackets and leaves to subsequent work.

1.1 Theoretical frame: the stimulus-organism-response model

The stimulus-organism-response (S-O-R) framework posits that environmental cues shape an individual's internal psychological state, which, in turn, drives their behavioral responses [1]. In live commerce, the broadcast serves as the environmental stimulus, the viewer's cognitive and emotional states represent the organism, and the final decision to purchase or return acts as the response [2,3]. This framework is highly appropriate for the current study because a livestream is essentially a managed environment of cues, where the host's delivery and the audience's reactions directly shape the viewer's impression of the seller.

Within that frame, streamer authenticity and social engagement are the two cues of interest, and consumer trust is the internal state most often invoked to explain why either should matter [4,5,6]. The persuasion literature distinguishes between a content-centered route, in which the viewer weighs what is said and who says it, and a peripheral route, in which contextual and affective cues carry the message [8]. Authenticity belongs, broadly, to the first; engagement to the second. The present study does not attempt to adjudicate between these routes or to trace how they combine. It asks the prior, simpler question of how strongly each of the three constructs relates to repurchase intention, holding the others constant, thereby specifying three direct associations rather than a chain.

1.2 Streamer authenticity and repurchase intention

Authenticity refers to the perception that a streamer is genuinely sincere. When a host acknowledges that a seasonal batch of fruit is small, offers unscripted opinions, or showcases products without flattering filters, viewers interpret these actions as genuine honesty rather than a calculated performance [9,10]. In agricultural live commerce, these cues are particularly valuable because product quality is difficult to evaluate remotely and

easily falsified; thus, a candid host reduces the purchase uncertainty that buyers cannot resolve through physical inspection [11]. A candid host also makes the broadcast more informative and more pleasant to watch, and both the credibility and the experience are carried forward to the next broadcast [12,13]. Authenticity should therefore increase the likelihood that a viewer will return to buy again.

H1: Streamer authenticity is positively associated with repurchase intention.

1.3 Social engagement and repurchase intention

Social engagement operates through a different mechanism; rather than serving as direct product endorsements, the likes, comments, and shares during a livestream function as collaborative acts that create a sense of shared presence for viewers and make the host feel accessible [14,15]. When a host acknowledges a viewer by name, answers questions in real time, or expresses gratitude for a share, the dialogue shifts the experience from an impersonal transaction between strangers to a personal interaction between acquaintances [7,16]. Participation of this kind is habit-forming: viewers who have contributed to a broadcast have invested something in it, and the broadcast becomes a place they return to as much as a shop they buy from [23,24]. Engagement should therefore be associated with a greater intention to purchase again.

H2: Social engagement is positively associated with repurchase intention.

1.4 Consumer trust and repurchase intention

Trust represents a buyer's willingness to rely on a seller under uncertain conditions; in online retail, it serves as the primary solution to the challenges of transacting with strangers at a distance [17,18,19]. When a buyer develops a belief in a host's reliability, they carry that confidence forward to future broadcasts, which lowers the perceived risk of purchasing again [20,21]. In live agricultural commerce, where every order requires taking a chance on unseen produce, this carry-over effect is the primary mechanism that transforms a one-time transaction into a long-term relationship [22]. Trust is accordingly entered here as a third predictor of repurchase intention, on an equal footing with the two broadcast features, so that its weight can be compared with theirs.

H3: Consumer trust is positively associated with repurchase intention.

Figure 1 integrates the three proposed hypotheses into a unified conceptual framework. Streamer authenticity, social engagement, and consumer trust are modeled as parallel predictors of repurchase intention (H1, H2, H3), with no directional relations assumed among them. The framework presents only the hypothesized associations. The results section reports the corresponding estimated coefficients.

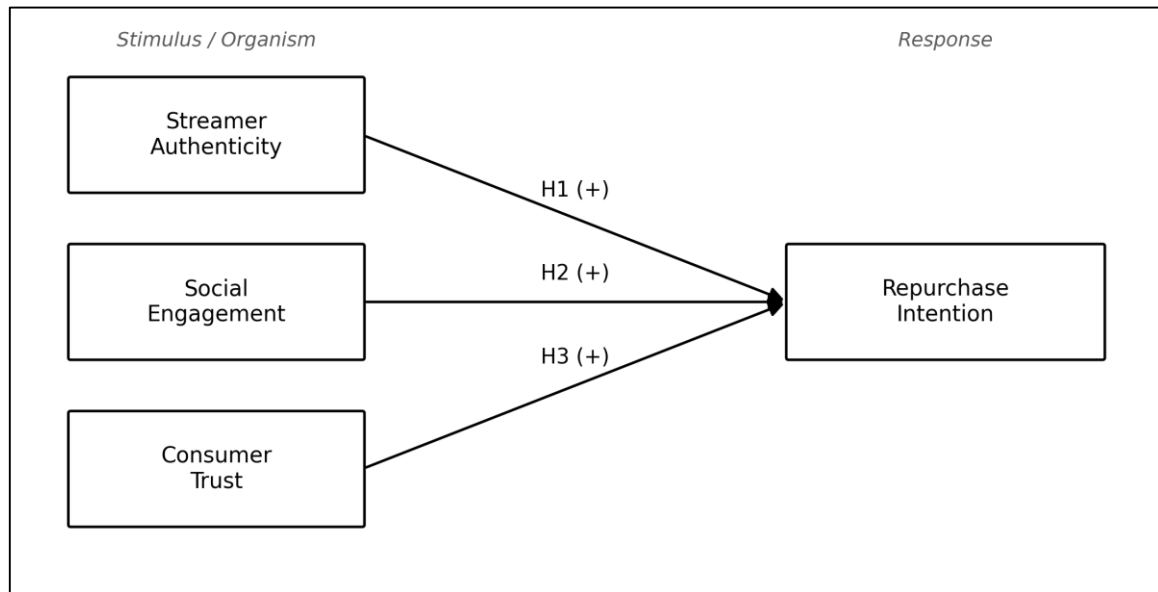


Figure 1. The proposed conceptual framework. Arrows denote the hypothesized positive associations with repurchase intention (H1-H3). N = 417.

2. METHODOLOGY

2.1 Design, population, and sample

This study used a cross-sectional online survey of consumers in Yunnan Province, a major agricultural hub in southwestern China, where livestreamed sales of local produce are already well established. The target population was adults who had purchased agricultural products through Douyin live streams; the experience needed to report meaningfully on repurchase. Respondents were recruited through a questionnaire distributed on the platform and screened for prior purchase before entry. After screening to remove incomplete or patterned responses, 417 valid cases were retained. This sample size comfortably exceeds

both the requirement for a 95% confidence level and the traditional ten-to-one ratio of cases to estimated parameters for the analyses conducted [25].

Demographically, women comprised 58.0% of the sample and men 42.0%. The respondents were primarily concentrated in the working-age, digitally active brackets that drive Douyin commerce: 44.4% were aged 21–30, and 28.8% were aged 31–40. Most participants held a bachelor's degree (61.2%), and monthly incomes were largely concentrated between 3,000 and 6,000 RMB (39.6%), with another 28.8% earning between 6,001 and 10,000 RMB. The full demographic profile is presented in Table 1.

Table 1. Respondent profile (N = 417).

Variable	Category	Frequency	Percentage (%)
Gender	Male	175	41.97
	Female	242	58.03
Age	Under 20	30	7.19
	21-30	185	44.36

Variable	Category	Frequency	Percentage (%)
	31-40	120	28.78
	41-50	60	14.39
	Above 50	22	5.28
Education	High school or below	95	22.78
	Bachelor's degree	255	61.15
	Master's or above	67	16.07
Monthly income	Below 3,000 RMB	70	16.79
	3,000-6,000 RMB	165	39.57
	6,001-10,000 RMB	120	28.78
	Above 10,000 RMB	62	14.86

2.2 Measures

All constructs were measured using multi-item, five-point Likert scales ranging from 1 (strongly disagree) to 5 (strongly agree), adapted from validated literature and tailored to the agricultural livestreaming context. Streamer authenticity was assessed with six items focusing on honesty, sincerity, and transparency, based on scales from Audrezet et al. [9], Wongkitrungrueng and Assarut [10], and Lou and Yuan [11]. Social engagement was evaluated using six items addressing liking, commenting, and sharing activities, drawn from Hajli [14], Sun et al. [15], and Wongkitrungrueng and Assarut [10]. Consumer trust was captured as a unidimensional construct via four items adapted from Gefen et al. [17] and McKnight et al. [18]. In comparison, repurchase intention was measured using four items from Hellier et al. [26].

To ensure semantic accuracy, the questionnaire was translated into Chinese and then back-translated. Content validity was verified by three experts using the item-objective congruence (IOC) index; all items scored between 0.67 and 1.00, exceeding the conventional 0.50 cutoff. A pilot study with 30 respondents was conducted before full deployment, and the final scale reliability was

verified using the complete dataset, as detailed in the results section.

2.3 Common method considerations

Because all variables were self-reported within a single survey session, common method variance was addressed through both procedural design and statistical testing. To reduce the motivation to respond consistently across different constructs, participants were assured of complete anonymity and informed that there were no correct or incorrect answers [27]. Harman's single-factor test was then conducted, revealing that the first unrotated factor accounted for only 37.6% of the variance. Because this is well below the standard 50% threshold, common method bias was not considered a significant threat to the validity of the findings.

2.4 Analytic strategy

The analysis was conducted in SPSS using a two-stage approach. First, the measurement properties of the four scales were evaluated by calculating Cronbach's alpha for internal consistency and examining corrected item-total correlations. An exploratory factor analysis, along with the Kaiser-Meyer-Olkin measure and Bartlett's test, was then used to confirm that the items loaded properly onto their four designated factors.

Second, the three hypotheses were tested in a single ordinary least squares regression in which repurchase intention was regressed simultaneously on streamer authenticity, social engagement, and consumer trust. Entering the predictors together, rather than in blocks or in a sequence of models, allows their relative weights to be read directly from the standardized coefficients. Multicollinearity was assessed using tolerance and variance inflation factor statistics, and the independence of residuals was assessed using the Durbin-Watson statistic. Mediation was not estimated: the study is concerned with the comparative strength of the three associations, and the causal architecture that would justify a mediated specification cannot be established with cross-sectional data [28,29].

3. RESULTS AND DISCUSSION

3.1 Measurement quality

All four scales demonstrated strong internal consistency. Cronbach's alpha values were

.851 for streamer authenticity, .847 for social engagement, .819 for consumer trust, and .815 for repurchase intention, all exceeding the standard .70 threshold [30]. Corrected item-total correlations ranged between .587 and .673, and because omitting any item would not have meaningfully increased the respective alpha value, all twenty items were retained.

The data met all requirements for factor analysis, indicated by a Kaiser-Meyer-Olkin measure of .928 and a significant Bartlett's test of sphericity ($\chi^2 = 3,546.964$, $df = 190$, $p < .001$). Principal components analysis with varimax rotation extracted four factors with eigenvalues greater than 1, explaining 66.7% of the total variance. Every item loaded above .66 on its target factor with no significant cross-loadings, confirming that streamer authenticity, social engagement, consumer trust, and repurchase intention are empirically distinct constructs. The reliability and validity metrics are summarized in Table 2

Table 2. Reliability and item analysis.

Construct	Items	Cronbach's alpha	CITC range	Interpretation
Streamer authenticity	6	.851	.602-.673	Good
Social engagement	6	.847	.587-.663	Good
Consumer trust	4	.819	.649-.673	Good
Repurchase intention	4	.815	.620-.661	Good

Note. CITC = corrected item-total correlation. N = 417.

3.2 Descriptive statistics and correlations

The construct scores fell within the moderate-to-high range. Consumer trust received the highest rating (M = 3.62, SD = 0.94), while the two livestream characteristics and repurchase intention clustered slightly lower (streamer authenticity: M = 3.26; social engagement: M = 3.28; repurchase intention: M = 3.23). This pattern indicates that buyers reported higher trust in a firm's intention to return than in the firm's actual return,

suggesting that trust alone does not fully determine the repurchase decision. All bivariate correlations were positive and significant at $p < .01$. Notably, authenticity ($r = .583$) and engagement ($r = .580$) correlated more strongly with repurchase intention than trust did ($r = .509$), an early indication of the ordering that the regression would confirm. The predictors were only moderately correlated with one another ($r = .380$ to $.521$), low enough to enter them in a single equation without collinearity

concerns. Table 3 reports the means, standard deviations, and correlations.

Table 3. Means, standard deviations, and correlations.

Variable	M	SD	RI	SA	SE	CT
RI	3.232	1.057	1.000			
SA	3.258	0.983	.583**	1.000		
SE	3.284	0.971	.580**	.380**	1.000	
CT	3.615	0.936	.509**	.439**	.521**	1.000

Note. RI = repurchase intention; SA = streamer authenticity; SE = social engagement; CT = consumer trust. ** $p < .01$. $N = 417$.

3.3 Predicting repurchase intention (H1-H3)

Regressing repurchase intention simultaneously on the three predictors supported all three hypotheses and established a clear ordering among them. The model explained just over half the variance in repurchase intention (R -squared = .507, adjusted R -squared = .503, $F(3, 413) = 141.380$, $p < .001$), a substantial figure for a three-predictor model of intention in a consumer setting. Streamer authenticity carried the largest weight ($\beta = .379$, $t = 9.663$, $p < .001$), supporting H1, with

social engagement close behind ($\beta = .353$, $t = 8.555$, $p < .001$), supporting H2. Consumer trust remained a significant predictor once the two broadcast features were held constant, but its weight was less than half theirs ($\beta = .158$, $t = 3.726$, $p < .001$), supporting H3. The estimates were not distorted by collinearity: tolerance ranged from .661 to .776, and variance inflation factors ranged from 1.29 to 1.51, well within conventional limits [25], and the Durbin-Watson statistic (2.10) indicated independent residuals. Table 4 reports the estimates.

Table 4. Regression predicting repurchase intention ($N = 417$).

Predictor	B	SE	β	t	p
(Constant)	-0.006	0.167	-	-0.038	.970
Streamer authenticity	0.408	0.042	.379	9.663	<.001
Social engagement	0.385	0.045	.353	8.555	<.001
Consumer trust	0.179	0.048	.158	3.726	<.001

Note. Dependent variable: repurchase intention. R -squared = .507; adjusted R -squared = .503; $F(3, 413) = 141.380$, $p < .001$. Durbin-Watson = 2.10. Tolerance = .661-.776; VIF = 1.29-1.51. $N = 417$.

3.4 Model summary and hypothesis tests

All three hypotheses were supported, and the model accounted for 50.7 percent of the variance in repurchase intention. What the buyer sees and does during the broadcast carries more weight than the trust that the broadcast has

accumulated: the two live-encounter features together dominate the equation, while trust contributes a smaller, though reliable, increment of its own. Figure 2 plots the tested model with its standardized coefficients, and Table 5 collects the formal test results.

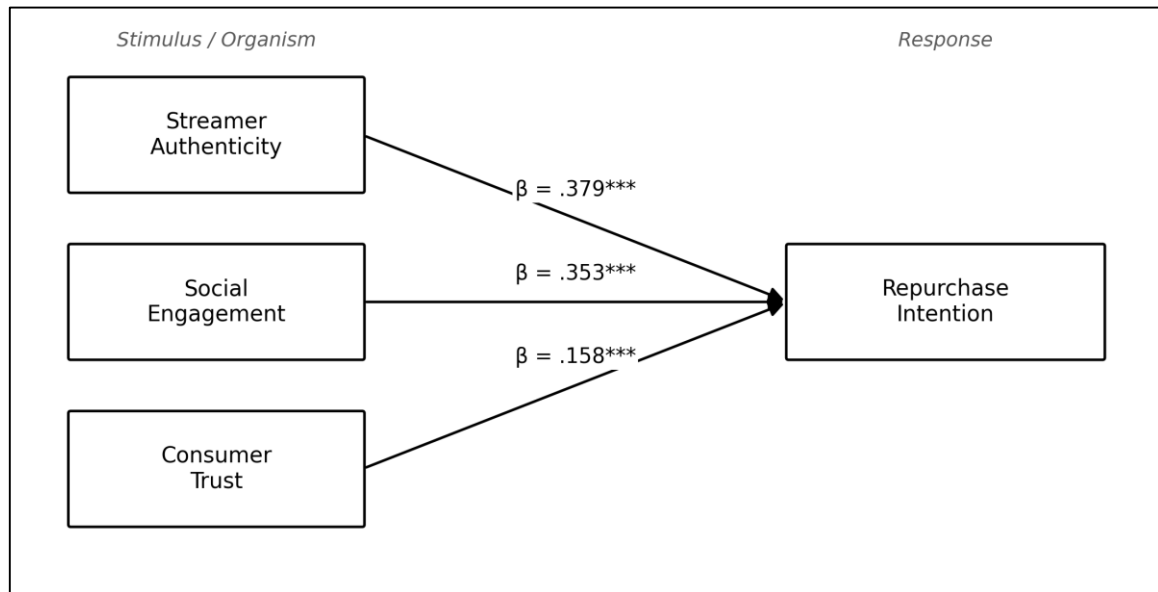


Figure 2. The tested model has standardized regression coefficients. *** $p < .001$. $N = 417$.

Table 5. Summary of hypothesis tests.

Hypothesis	Path	Estimate	p	Result
H1	SA -> RI	$\beta = .379$	<.001	Supported
H2	SE -> RI	$\beta = .353$	<.001	Supported
H3	CT -> RI	$\beta = .158$	<.001	Supported

Note. SA = streamer authenticity; SE = social engagement; CT = consumer trust; RI = repurchase intention. Estimates are standardized regression coefficients from the model in Table 4. $N = 417$.

3.5 Discussion

Read together, the results qualify the trust-centered consensus in the live-commerce literature. Trust is commonly treated as the pivot on which repeat buying turns, and the present data do not contradict the claim that it matters: its association with repurchase intention was positive, significant, and robust to the inclusion of the two broadcast features. What the data question is its primacy. When authenticity, engagement, and trust compete for the same variance, the two features of the live encounter prove roughly twice as influential as the accumulated trust that the encounter is supposed to produce. That buyers reported more trust than intention to return points in the same direction: trust was plentiful in this

sample, and yet it was not what most strongly distinguished those who meant to buy again.

Two readings of this pattern are worth setting out. First, the influence of a candid host and a lively comment stream reaches the buyer through channels that do not require a deliberate judgment about the seller's reliability: the informativeness of a good demonstration and the enjoyment of taking part are themselves reasons to come back [22,24]. On the second, trust does part of its work through the very cues that accompany it, so that its independent contribution understates its total importance. The present design cannot distinguish these accounts, and the honest conclusion is comparative rather than mechanistic: in agricultural live commerce, the quality of the encounter

predicts the return visit more strongly than the trust accumulated. Establishing how the three constructs are causally arranged is the natural next task, and it requires a design in which the temporal ordering of the measures is not assumed but observed.

The practical implications follow from the ordering of the coefficients. Because authenticity carried the largest weight, hosts should be trained to speak candidly about the produce, including its shortcomings, and to avoid the polished sales register that viewers now discount. Because engagement followed closely, the comment stream should be treated as a conversation rather than a backdrop: viewers who are acknowledged by name and answered in real time are the viewers who return. Because trust contributed a smaller independent increment, it is best regarded as an asset that accrues from doing the first two things well, rather than as a separate objective that can be pursued through reassurance alone.

Three limitations bound these conclusions. The data are cross-sectional and self-reported, so the associations reported here do not establish causal direction, and repurchase intention serves as an imperfect proxy for repurchase behavior. The sample is confined to one Chinese province and one platform, which serves the aim of contextual depth but limits generalization to other regions, product categories, and live-commerce ecosystems. The model is also deliberately compact: it estimates three direct associations and leaves aside the mediating and moderating architecture through which these constructs may in fact be related. That architecture is the object of a companion study; the present paper establishes the baseline against which any such elaboration must earn its keep.

4. CONCLUSIONS

This study asked how strongly streamer authenticity, social engagement, and consumer

trust are each associated with the intention to buy agricultural produce again from a Douyin live stream. Testing three direct hypotheses among 417 buyers in Yunnan Province, the study found that all three were supported, with the model accounting for just over half the variance in repurchase intention. The ordering of the coefficients is the substantive result: authenticity ($\beta = .379$) and engagement ($\beta = .353$) outweighed trust ($\beta = .158$) by more than two.

Theoretically, the finding recommends caution about accounts that place trust at the center of live commerce, and it supplies a compact stimulus-organism-response baseline against which richer models can be judged. In practice, it points sellers of unbranded farm goods to the two things they can control directly in any given broadcast: a visibly honest host and an audience that is genuinely engaged. Future work should follow buyers over time, measure behavior rather than intention, and test whether the modest independent weight of trust observed here survives a design capable of tracing how trust is formed and what it transmits.

5. ACKNOWLEDGMENTS

The authors thank the experts who reviewed the research instrument, the respondents who completed the questionnaire, and the International College, Rajamangala University of Technology Krungthep, for its support of this research.

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Tasting through the screen: media content quality, perceived media influence, and tourists' attitudes towards food tourism in Bangkok, Thailand

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ABSTRACT

Digital media now stand between the tourist and the table, yet little is known about how the quality of food-related content translates into the attitudes that sustain its use. Drawing on the elaboration likelihood model and the information adoption model, this study examines whether the perceived quality of media content shapes tourists' attitudes towards using online media for food tourism, and whether perceived media influence carries that effect. A cross-sectional survey using convenience sampling collected data from 386 tourists in Bangkok across two collection waves in 2024, analyzed with regression-based mediation analysis (PROCESS Model 4, 5,000 bootstrap resamples) and complemented by partial least squares structural equation modeling. In simple regression, content quality exerted a strong positive effect on perceived media influence ($\beta = .741$); in the mediation model, controlling for content quality, perceived influence in turn predicted media-use attitude and satisfaction ($\beta = .573$), while the direct quality-attitude path remained significant ($\beta = .312$). Perceived influence partially mediated the quality-attitude relationship (standardized indirect effect = .425, 95% CI [.316, .533]), and the model explained 69.1% of the variance in media-use attitude. The findings extend information adoption research into gastronomy tourism and indicate that credible, accurate, and visually engaging content—rather than volume of exposure—is the lever through which destination marketers can convert screen time into culinary travel. The implications for destination marketing organizations, content creators, and platform strategy in Bangkok's food-tourism economy are discussed.

Keywords: food tourism, social media, information adoption, media content quality, mediation analysis, Bangkok

1. INTRODUCTION

Food has moved from the periphery of travel to its center. For an increasing share of visitors, what and where they will eat is decided before any monument or museum

is included in the itinerary, and the meal itself has become the attraction rather than its accompaniment [1]. Bangkok occupies a privileged position in this economy of taste. The city's street-food culture is a recurring

motif in global gastronomy rankings and travel journalism, and culinary experiences feature prominently in Thailand’s national tourism positioning.

The route to the table, however, now runs through a screen. Tourists encounter destinations as photographs, short videos, and reviews long before they encounter them as places, and electronic word-of-mouth has become one of the most consequential sources of information in travel decision-making [2,3]. Food is arguably the most mediatized of all tourism products: it is visual, shareable, and inexpensive to sample, which makes platforms such as Facebook, Instagram, and YouTube, as well as review communities such as Wongnai, Pantip, and TripAdvisor, the natural arenas in which culinary reputations are made. Whether the content circulating in that arena actually changes what tourists do—and how they come to regard the media they rely on—is a question of direct commercial and theoretical interest.

Existing research offers only a partial answer. Studies of social media and destination choice typically treat influence as a uniform outcome and pay limited attention to the qualities of the content that produces it; Tham et al. [3] show that such influence is strongly contingent on context. The information adoption tradition, by contrast, specifies the mechanism—argument quality operating through perceived usefulness towards adoption [4,5]—but has rarely been carried into gastronomy tourism, and seldom

in South-East Asian settings. Recent regional work illustrates both the momentum and the gap: Jongsuksomsakul [16] documents media co-creation around traditional Thai gastronomy, Soonsan et al. [17] link local food and social-media sharing to the Phuket travel experience, Mohd Salim et al. [18] model a double-mediation pathway from destination social-media foodscape to visit intention in a Malaysian setting, and recent reviews confirm that social-media involvement with local food shapes memorable tourism experience more broadly [19,20]. None of these studies, however, traces the sequence from content quality through perceived influence to the attitude tourists form towards the media itself—the mechanism this study isolates. What remains untested is the chain that matters most to practitioners: does better content produce a stronger sense of influence, and does that sense of influence cultivate the favorable attitudes that keep tourists returning to these channels?

This study addresses that gap. Using survey data from 386 tourists surveyed in Bangkok during 2024, it models the relationships among media content and format quality (MCC), perceived media influence on food-travel decisions (MIN), and media-use attitude and satisfaction (MSA). Three contributions follow. First, the study extends the elaboration likelihood model and the information adoption model into the food-tourism domain, treating media-use attitude as the downstream consequence of

adoption rather than stopping at intention. Second, it quantifies the mediating role of perceived influence, showing that content quality works chiefly, but not exclusively, through it. Third, it offers destination marketers in Bangkok evidence on which content properties—credibility, accuracy, visual appeal—are worth their investment.

The remainder of the paper proceeds as follows. Section 2 develops the conceptual framework and hypotheses. Section 3 describes the data and method. Section 4 reports the results, and Section 5 discusses their theoretical and managerial implications, followed by the limitations and conclusion.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Food Tourism in a Mediatized Marketplace

Food tourism denotes travel in which the consumption, appreciation, or experience of food is a primary motivator [1]. The sector rewards destinations that can convert culinary distinctiveness into visitation, and Bangkok's street markets, Chinatown food stalls, and night bazaars have proven especially convertible. However, culinary capital is perishable: it must be continuously displayed to be consumed, and display now happens on social platforms. User reviews, influencer videos, and destination campaigns compete for the same scarce attention, and the tourist's impression of a city's food scene is

assembled largely from this mediated mosaic. Understanding how the properties of that content register with tourists is therefore not a peripheral media question but a core marketing one.

2.2 Theoretical Anchors: Elaboration Likelihood and Information Adoption

Two complementary frameworks specify how mediated information becomes behavioural influence. The elaboration likelihood model [6] distinguishes between a central route, in which message recipients scrutinize argument quality, and a peripheral route, governed by cues such as attractiveness. The information adoption model [4] extends this logic to computer-mediated settings: argument quality and source credibility shape perceived usefulness, which in turn determines whether information is adopted. Erkan and Evans [5] extended the model to social media, showing that the quality, credibility, and usefulness of electronic word-of-mouth jointly drive consumers' information adoption and subsequent purchase intentions. Applied to food tourism, the frameworks imply a sequence: tourists who judge food-related content as well-crafted and trustworthy should perceive it as genuinely influential in their travel decisions, and repeated experiences of useful influence should consolidate into a favorable attitude towards the media themselves.

2.3 Media Content and Format Quality

Content quality in this study spans the visual and informational properties of food-tourism media: the attractiveness and aesthetic quality of images, the credibility of the information conveyed, its concision and accessibility, and its factual accuracy. These properties correspond to argument quality and peripheral visual cues simultaneously—food content persuades through the eye as much as through the proposition. Filieri and McLeay [7] demonstrate that information quality dimensions predict travelers’ adoption of online reviews; in the culinary domain, where the product cannot be tasted remotely, the burden carried by imagery and credible description is heavier still. Tourists who find content attractive, credible, and accurate should accordingly experience it as influential when choosing where to eat and travel, and the same judgment of quality should color their overall evaluation of using such media. Hence:

H1. Media content and format quality positively affect perceived media influence on food-tourism decisions.

H3. Media content and format quality positively affect attitude towards and satisfaction with using online media for food tourism.

2.4 Perceived Media Influence and Media-Use Attitude

Perceived media influence captures the tourist’s acknowledgment that online media, reviews, and advertising genuinely shape their food-travel decisions—the experiential analog of information adoption. When adoption is rewarding, the user’s evaluation of the channel improves: satisfaction with platforms and a positive attitude towards consulting them again are the natural sediment of repeated useful influence [2,5]. The information adoption logic further implies that quality does not act on attitude only directly; much of its effect should travel through the experience of influence itself. These arguments yield the remaining hypotheses:

H2. Perceived media influence positively affects attitudes towards and satisfaction with using online media for food tourism.

H4. Perceived media influence mediates the relationship between media content quality and media-use attitude and satisfaction.

2.5 Conceptual Model

Figure 1 summarises the hypothesized model: content quality drives perceived influence (H1), perceived influence drives media-use attitude (H2), quality retains a direct path

to attitude (H3), and the indirect path through influence constitutes the mediation hypothesis (H4).

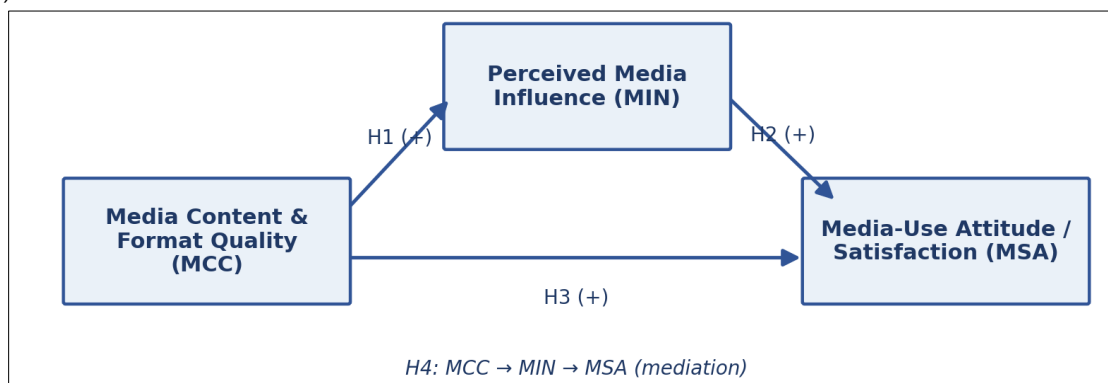


Figure 1. Conceptual Model

3. METHODOLOGY

3.1 Design, Sample, and Procedure

A cross-sectional questionnaire survey using convenience sampling was administered to tourists aged 18 years or older who had experienced food-related travel in Bangkok within the preceding 12 months of participation. Data collection took place at popular food-tourism venues in Bangkok during 2024, in two collection waves using identical items, yielding a pooled sample of 386 after screening (wave 1, $n = 200$; wave 2, $n = 186$). The questionnaire was administered in Thai. Participation was voluntary and anonymous, and respondents were informed that the data would be used solely for research. Independent-samples t -tests compared the two waves on the three study constructs before pooling; wave 1 respondents scored significantly higher than wave 2 on media content and format quality ($M = 6.26$ vs. 5.90 , $t(384) = 5.26$, $p < .001$), perceived media influence ($M = 6.33$ vs. 5.65 , $t(384) = 8.31$, $p < .001$), and media-use

attitude and satisfaction ($M = 6.38$ vs. 5.77 , $t(384) = 7.39$, $p < .001$). The waves were nonetheless pooled because they used an identical instrument and identical eligibility criteria; the mean-level difference is treated as a limitation of the pooled analysis (Section 6) rather than as grounds for analysing the waves separately, and a wave-controlled sensitivity analysis is recommended before the pooled coefficients are generalised beyond the 2024 collection period. The sample comfortably exceeds the inverse-square-root requirement for detecting minimum path coefficients of about .15 at the 5% level [8], as well as the conventional 10-times rule.

Table 1 profiles the sample. Women constituted the majority (58.5%), and two-thirds of respondents were aged 26–45. Half were single, and private-company employment was the most common occupation. Most respondents reported spending up to 5,000 THB per food-related search or restaurant visit. The instrument used to build this pooled dataset did not

include a nationality item, so the sample cannot be disaggregated by Thai versus international status; this is addressed as a limitation in Section 6.

Table 1. Sample profile (n = 386). On spending, five cases had a fully missing response; the “Other/unspecified” category (n = 26) denotes a non-numeric response (e.g., “no fixed amount”) rather than missing data. Time online: 31.6% searched food content 1–2 times per week, and 34.2% 1–2 times per month; viewing photographs of attractions was the most common online activity (44.3%).

Characteristic	Category	n	%
Gender	Male	144	37.3
	Female	226	58.5
	Other	16	4.1
Age	18–25	58	15.0
	26–35	147	38.1
	36–45	118	30.6
	46–55	48	12.4
	Over 55	15	3.9
Marital status	Single	195	50.5
	Married/civil partner	173	44.8
	Divorced/separated	13	3.4
	Widowed/other	5	1.3
Occupation	Government/state enterprise	41	10.6
	Private company employee	146	37.8
	Homemaker	124	32.1
	Business owner	68	17.6
	Other	7	1.8
	Other/unspecified	26	6.7
Spending per food search/visit	≤3,000 THB	111	28.8
	3,001–5,000 THB	168	43.5
	5,001–10,000 THB	57	14.8
	More than 10,000 THB	19	4.9
	Other/unspecified	26	6.7

3.2 Measures

All constructs were measured reflectively on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). Media content and format quality (MCC) comprised six items covering the attractiveness and

aesthetics of imagery, the influence of pictures on destination choice, and the credibility, concision, and accuracy of content. Perceived media influence (MIN) comprised five items on the influence of online media, advertising, and reviews on

food-travel decisions. Media-use attitude and satisfaction (MSA) comprised seven items on satisfaction with using specific online media for food-tourism information: Facebook, Instagram, web pages (Wongnai), TripAdvisor, Pantip, YouTube, and Twitter/X. Content validity was established before fieldwork through an expert panel using the index of item-objective congruence (IOC), with items retained only when they met the conventional threshold ($IOC \geq .50$). A pilot test preceded the main survey and confirmed acceptable internal consistency for all three scales before full-scale data collection began.

3.3 Analytical Approach

Analyses were conducted in IBM SPSS. After descriptive and reliability analyses, the hypothesized paths were estimated using ordinary least squares regression, and the mediation hypothesis was tested with the PROCESS macro (Model 4) using 5,000 percentile bootstrap resamples [9]. Sampling adequacy and dimensionality were examined through principal component analysis with the Kaiser–Meyer–Olkin statistic and Bartlett’s test. Common method variance was probed with the single-factor test [10]. A complementary partial least squares structural equation model (PLS-SEM), recommended for prediction-oriented

composite models [11], is reported in Section 4.5.

4. RESULTS

4.1 Preliminary Analyses

Sampling adequacy was excellent ($KMO = .954$), and Bartlett’s test of sphericity was significant, $\chi^2(153) = 4,718.51$, $p < .001$, confirming the factorability of the 18-item correlation matrix. Principal component analysis extracted a dominant first component accounting for 54.2% of the total variance. Because a single factor exceeded half of the common variance, common method variance cannot be ruled out; procedural remedies—anonymity, separation of construct blocks, and neutral wording—were applied at the design stage, and the limitation is acknowledged in Section 6 [10].

4.2 Reliability

Internal consistency was satisfactory for every scale (Table 2): $\alpha = .812$ for MCC, .883 for MIN, and .923 for MSA, with an overall instrument alpha of .948. One MCC item (attractiveness of images) showed a weak corrected item-total correlation (.205; alpha-if-deleted .845); it was retained for the regression analyses to preserve the instrument’s content coverage, and its behavior is re-examined in the PLS-SEM measurement model (Section 4.5).

Table 2. Reliability statistics ($n = 386$)

Scale	Items	Cronbach’s α
Media content & format quality (MCC)	6	.812
Perceived media influence (MIN)	5	.883

Media-use attitude and satisfaction (MSA)	7	.923
Overall instrument	18	.948

4.3 Regression Analysis

Three regressions established the bivariate architecture of the model (Table 3). Content quality predicted perceived influence, $\beta = .741$, $R^2 = .549$, $F(1, 384) = 466.50$, $p < .001$, supporting H1. Content quality also predicted media-use attitude when entered alone, $\beta = .737$, $R^2 = .542$, $F(1, 384) = 455.26$, $p < .001$, and perceived influence was the strongest single predictor of attitude, $\beta = .804$, $R^2 = .647$, $F(1, 384) = 703.21$, $p < .001$, consistent with H2 and H3.

Table 3. Simple regression results (n = 386). *** p < .001.

Model	Path	B	SE	β	t	R ²	F
1	MCC → MIN	.926	.043	.741	21.60***	.549	466.50
2	MCC → MSA	.907	.043	.737	21.34***	.542	455.26
3	MIN → MSA	.793	.030	.804	26.52***	.647	703.21

4.4 Mediation Analysis

The mediation model was estimated with PROCESS Model 4 (X = MCC, M = MIN, Y = MSA; 5,000 bootstrap resamples). With both predictors entered, the model explained 69.1% of the variance in media-use attitude, $F(2, 383) = 427.77$, $p < .001$. Perceived influence remained the dominant predictor ($B = .565$, $SE = .042$, $\beta = .573$, $t = 13.55$, $p < .001$), supporting H2, while the direct effect of content quality stayed significant ($B = .384$, $SE = .052$, $\beta = .312$, $t = 7.38$, $p < .001$), supporting H3. The indirect

effect of content quality on attitude through perceived influence was $B = .523$ (BootSE = .069, 95% CI [.388, .655]); in completely standardized form, .425 (BootSE = .056, 95% CI [.316, .533]). As the bootstrap interval excludes zero and the direct effect remains significant with the same sign, the pattern constitutes complementary partial mediation [12]: roughly 58% of the standardized total effect (.737) travels through perceived influence. H4 is supported. Figure 2 summarises the estimates.

Table 4. Mediation results, PROCESS Model 4 with 5,000 percentile bootstrap resamples (n = 386).

Effect	B	BootSE / SE	95% CI	Standardised
Total effect MCC → MSA	.907	.043	[.823, .990]	.737
Direct effect MCC → MSA (c')	.384	.052	[.282, .487]	.312
Indirect effect MCC → MIN → MSA	.523	.069	[.388, .655]	.425 [.316, .533]

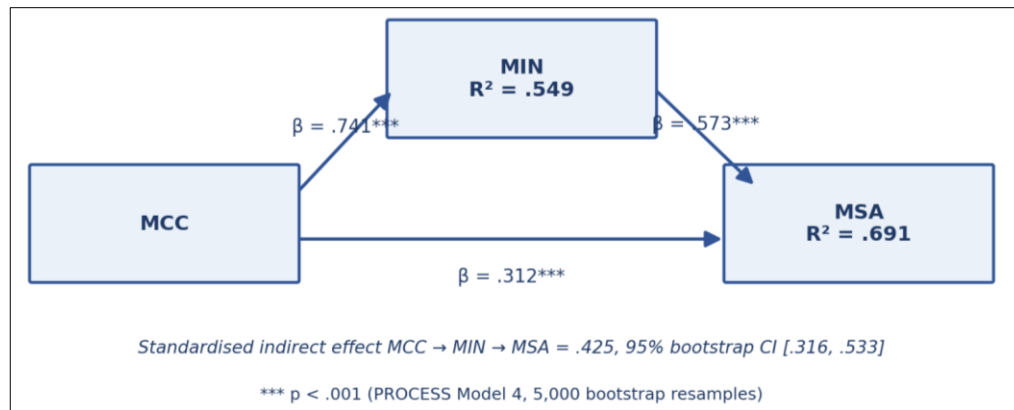


Figure 2. Structural results (standardized coefficients; PROCESS Model 4)

4.5 Structural Equation Model (PLS-SEM)

The model was re-estimated as a PLS-SEM in SmartPLS 4 (path-weighting scheme, Mode A; 5,000 percentile bootstrap resamples). The weak content-quality item identified in the reliability analysis (attractiveness of images) loaded at .248 and was removed, leaving five MCC indicators; all retained loadings exceeded .76 and were significant ($t \geq 25.66$). Construct reliability and convergent validity were satisfactory (Table 5): Cronbach's α ranged from .845 to .923, composite reliability (ρ_c) from .893 to .939, and AVE from .624 to .687. Discriminant validity was supported on both criteria: each construct's $\sqrt{\text{AVE}}$ (.790–.829) exceeded its correlations with the other constructs (.766–.808) [13], and all HTMT ratios remained below the .90 threshold [14,15] (MCC–MIN = .879; MCC–MSA = .861; MIN–MSA = .890).

Inner-model collinearity was unproblematic ($\text{VIF} = 2.42$), and the model achieved an SRMR of .069, below the .08 guideline. The structural estimates (Table 6) replicate the regression pattern: content quality strongly predicted perceived influence ($\beta = .766$, $t = 28.10$), perceived influence predicted media-use attitude ($\beta = .524$, $t = 8.56$), and the direct quality–attitude path remained significant ($\beta = .370$, $t = 6.22$), with $R^2 = .586$ (MIN) and .709 (MSA) and effect sizes f^2 of 1.416, .391, and .195 respectively. The specific indirect effect $\text{MCC} \rightarrow \text{MIN} \rightarrow \text{MSA}$ was .402 ($t = 7.90$, 95% CI [.300, .498]); with a significant same-sign direct effect, the PLS-SEM confirms complementary partial mediation (52% of the total effect of .772 mediated), corroborating H1–H4 in full.

Table 5. LS-SEM measurement model (SmartPLS 4, $n = 386$). All loadings are significant at $p < .001$. Fornell–Larcker satisfied: $\sqrt{\text{AVE}}$ (.790/.826/.829) exceeds inter-construct correlations (.766–.808); HTMT all $< .90$.

Construct	Item	Loading	α	CR (ρ_c)	AVE
MCC	MCC2–MCC6 (MCC1 removed, loading .248)	.775–.824	.845	.893	.624

MIN	MIN1-MIN5	.795-.848	.883	.915	.682
MSA	MSA1-MSA7	.765-.870	.923	.939	.687

Table 6. PLS-SEM structural model (5,000 percentile bootstrap resamples). $R^2(\text{MIN}) = .586$; $R^2(\text{MSA}) = .709$; SRMR = .069; all $p < .001$.

Hypothesis	Path	β	t	95% CI	f^2	Decision
H1	MCC $\rightarrow$ MIN	.766	28.10	[.710, .818]	1.416	Supported
H2	MIN $\rightarrow$ MSA	.524	8.56	[.398, .635]	.391	Supported
H3	MCC $\rightarrow$ MSA	.370	6.22	[.256, .491]	.195	Supported
H4	MCC $\rightarrow$ MIN $\rightarrow$ MSA	.402	7.90	[.300, .498]	—	Supported (partial mediation)

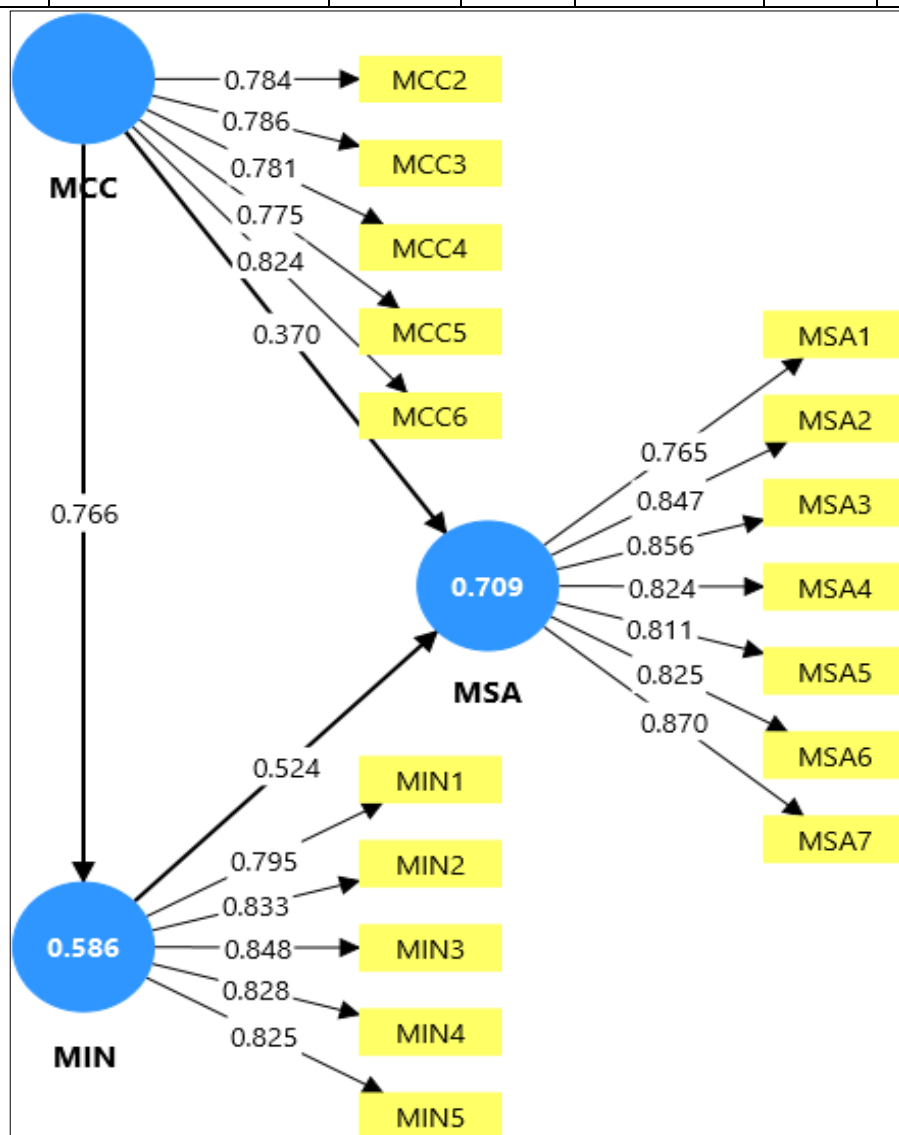


Figure 3. PLS-SEM estimation results (SmartPLS 4): outer loadings, standardized path coefficients, and R^2 values ($n = 386$).

5. DISCUSSION

5.1 Key Findings

Three results carry the argument. First, the quality of food-tourism content is a strong antecedent of perceived media influence: the MCC $\rightarrow$ MIN path ($\beta = .741$) indicates that tourists do not report being influenced by seeing much content; they report being influenced when the content they see is attractive, credible, concise, and accurate. Second, perceived influence converts into favorable media-use attitudes ($\beta = .573$, with quality controls), confirming that adoption experiences sediment into channel evaluations. Third, quality retains a direct attitudinal effect ($\beta = .312$) beyond what influence carries, so the mediation is partial rather than full—well-crafted content is appreciated even when a given decision is not visibly swayed by it. Together, the two predictors account for 69.1% of the variance in tourists' attitude towards food-tourism media.

5.2 Theoretical Implications

The findings extend the information adoption model [4] in two directions. The model's usual terminus is adoption or purchase intention [5]; here, the chain is carried one step further to the attitude towards the medium itself, and that step accounts for more than two-thirds of the attitude's variance. For gastronomy tourism specifically, the results qualify the contextual skepticism of Tham et al. [3]: social media

influence may indeed be contingent, but in a domain as visual and low-risk as food, content quality alone reproduces most of the influence mechanism. The strong contribution of the credibility and accuracy items within MCC also echoes the central-route emphasis of the elaboration likelihood model [6]—even in an aesthetically driven category, tourists appear to process culinary content as argument rather than merely as spectacle. The platform-based measurement of media-use satisfaction (Facebook, Instagram, Wongnai, TripAdvisor, Pantip, YouTube, Twitter/X) further suggests that tourists evaluate their media repertoire as a coherent whole: a single reliable scale ($\alpha = .923$) spanned seven platforms.

5.3 Practical Implications

For Bangkok's destination marketing organizations and tourism authorities, the managerial reading is direct: invest in the craft of content before it reaches. Campaigns that prioritize accurate information, credible sourcing, and high production values should outperform volume-led strategies, because quality is the variable that moves perceived influence and, through it, the attitudes that keep tourists consulting these channels. The behavioral profile sharpens the prescription: viewing photographs of attractions was respondents' most common online activity, and weekly or monthly food searches were the norm, so visually persuasive content placed in routine feeds—rather than burst

campaigns—matches actual usage rhythms. For restaurateurs and street-food vendors, the credibility items matter most: exaggerated imagery that the meal cannot honor risks damaging precisely the perceptions that drive adoption. For content creators, concision and factual reliability are not constraints on creativity but conditions of persuasive force, and consistency across the platform repertoire is likely to outperform platform-specific gimmickry.

6. LIMITATIONS AND FUTURE RESEARCH

Several limitations bound these conclusions. The design is cross-sectional and the data self-reported, so the paths represent theoretically ordered associations rather than demonstrated causation; the dominant first component in the method-variance check (54.2%) means common method variance may inflate the absolute size of the coefficients, even if it is unlikely to manufacture the pattern. One content-quality item (image attractiveness) showed weak discrimination and was removed from the PLS-SEM measurement model; the scale should be revisited in future refinements. The sample, while adequately powered, was convenience-sampled in a single city, and the survey instrument did not record respondents' nationality, so the extent to which international tourists are represented is unknown; the sample is accordingly described here as tourists in Bangkok rather than as a verified Thai/international mix. The two collection waves also differed

significantly in mean level on all three constructs (Section 3.1); pooling was justified by the identical instrument and eligibility criteria used in both waves, but the pooled coefficients should be treated as provisional pending a wave-controlled sensitivity analysis. The unusually high Homemaker share (32.1%) may reflect the venues, days, and times at which the convenience sample was recruited rather than the population of Bangkok food tourists generally; future studies should report, and where possible weight for, such venue- and time-of-day sampling effects. Experimental manipulation of content quality, longitudinal panels linking media attitudes to actual visitation, platform-specific comparisons, and contrasts between domestic and international tourists — for which nationality would need to be recorded — are natural next steps.

7. CONCLUSION

Food tourism is increasingly decided on screens, and this study shows that what happens on those screens is governed less by what tourists see than by how good it is. In a model explaining over two-thirds of the variance in tourists' attitudes towards food-tourism media, content quality emerged as the dominant upstream force, working chiefly through the experienced influence of media on real decisions. For a city whose kitchens are already world-famous, the message to Bangkok's marketers is encouragingly tractable: the next tourist meal is won with credible, beautiful, and accurate content.

8. ACKNOWLEDGMENTS

The author gratefully acknowledges Rajamangala University of Technology Krungthep for the institutional support that enabled this study. Sincere thanks are extended to the expert panel who evaluated the questionnaire's content validity, and to all respondents who generously gave their time during data collection in Bangkok. Finally, the author sincerely thanks the staff and students of the Department of Tourism, Faculty of Liberal Arts, for their kind assistance. This research received no external funding.

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The impact of social media influencers' characteristics on intention to purchase: the mediating role of attitude toward the influencer on TikTok in Thailand

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ABSTRACT

TikTok has become the trending platform worldwide, standing out from others because of its short-video format. Marketers increasingly use influencers on TikTok to present products in a way that does not feel forced, so the way people receive information on TikTok differs from other platforms. Source Credibility Theory is widely accepted to explain this persuasion: when consumers perceive a source as credible, their attitude changes. The theory has three dimensions, trustworthiness, expertise, and attractiveness, which have been studied extensively on platforms such as Instagram but far less on short-video platforms like TikTok, and the mediating role of attitude toward the influencer has received little attention. This study therefore treats attitude toward the influencer as a mediator linking the three dimensions to purchase intention in the TikTok context in Thailand. Data came from a quantitative cross-sectional survey of Thai TikTok users who follow influencers; after screening, 109 valid responses remained and were analysed with PLS-SEM. Recruitment was by convenience, and the sample consists mainly of young, heavy TikTok users, so the findings describe this segment rather than Thai TikTok users in general. Attractiveness drove attitude most strongly. Trustworthiness directly affected both attitude and purchase intention, while expertise showed no significant effect on either. Attitude partially mediated trustworthiness and fully mediated attractiveness, but did not mediate expertise. The three dimensions therefore do not carry equal weight and cannot be applied universally: their effect depends on the platform and content type, and attitude toward the influencer is the main factor that turns credibility into purchase intention.

Keywords: source credibility, social media influencer, attitude toward the influencer, purchase intention, TikTok, PLS-SEM

1. INTRODUCTION

TikTok now anchors short-form video: it is one of the most influential forces in digital marketing today. Its global user base is vast, still growing fast, and spends heavily on in-app content [1]. This reach has changed where promotional money goes: brands increasingly channel it through social media influencers, whose endorsements arrive as native, entertaining clips rather than overt advertising [2,3]. The platform itself is also distinctive. Its short, entertainment-led videos have little in common with the curated, static posts that dominate platforms such as Instagram, or with the long-form videos of YouTube [4]. Source credibility theory addresses a basic question in persuasion: why some communicators change minds and others do not. Its core claim is simple. A source the receiver sees as credible produces greater attitude change [5,6]. Ohanian carried this into marketing, operationalising credibility as trustworthiness, expertise, and attractiveness [7], and that three-part structure remains the dominant framework for endorser research [8,9]. Although source credibility has been examined extensively for celebrities and Instagram influencers [10-13], far less is known about how its dimensions operate on short-form video platforms such as TikTok, where audiences are younger and content is built around entertainment rather than information [4,14]. Research on TikTok itself has begun to close this gap, with influencer credibility shown to drive purchase intentions among TikTok users [15], and recent work grounded in source credibility theory confirms the positive effect of influencers' credibility on consumer attitudes [16]. Moreover, much prior work links credibility directly to behavioural intention while paying less attention to the attitudinal mechanism through which credibility is converted into intention [17,18]. Clarifying this mechanism matters because attitude toward the influencer captures the receiver's overall evaluative response and is a proximal

antecedent of behaviour [19]. This study therefore models attitude toward the influencer as the mediator linking the three credibility dimensions to intention to purchase, and tests both direct and mediated effects in the TikTok setting in Thailand. Trustworthiness refers to the degree to which an audience perceives an influencer as honest and dependable. Trusted endorsers reduce perceived risk and foster favourable evaluations and stronger purchase intentions [20,21]. Accordingly, H1: trustworthiness positively affects attitude toward the influencer; H5: trustworthiness positively affects intention to purchase. Expertise refers to the extent to which an influencer is seen as knowledgeable and qualified in the endorsed domain. Expert sources are generally more persuasive and have been linked to favourable attitudes and intentions [7,22,23]. Thus, H2: expertise positively affects attitude toward the influencer; H6: expertise positively affects intention to purchase. Attractiveness captures the physical and social appeal of the influencer. Attractive communicators draw attention and transfer positive affect to evaluations and behaviour [11,24,25]. Hence, H3: attractiveness positively affects attitude toward the influencer; H7: attractiveness positively affects intention to purchase. Attitude toward the influencer is an enduring evaluative orientation that is widely treated as a strong proximal predictor of behavioural intention [17,26]. A favourable attitude toward the influencer is expected to raise the likelihood of purchasing the endorsed product [19]. Therefore, H4: attitude toward the influencer positively affects intention to purchase. Figure 1 presents the conceptual framework. Three contributions follow from this design. First, the study takes source credibility theory into short-form video, where it has rarely been tested. Second, it treats attitude toward the influencer not as a side variable but as the central mechanism through which credibility becomes intention. The third

contribution is empirical: evidence from the Thai TikTok market, which is growing rapidly yet remains under-studied.

construct [27,28]. Data were collected between September and November 2024. To limit common method variance, participation was voluntary and all constructs were measured with items adapted

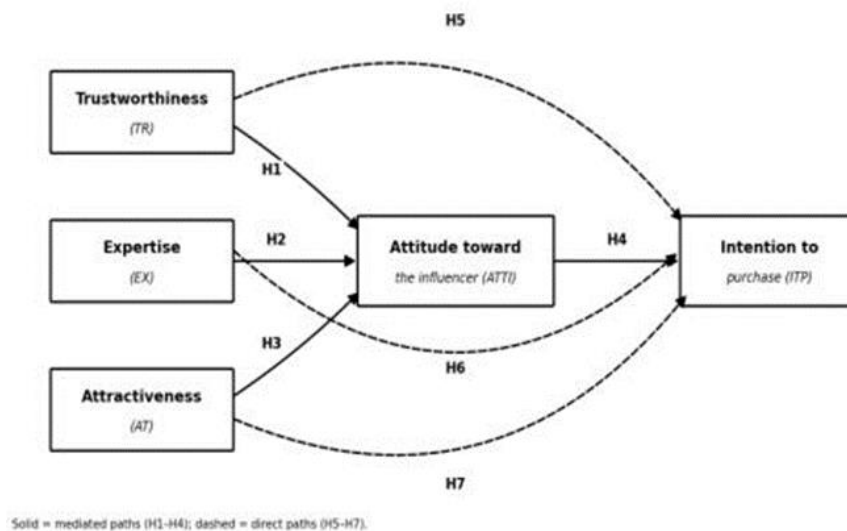


Figure 1. Conceptual framework of the study

2. MATERIALS AND METHODS

The study is quantitative and rests on a cross-sectional survey. Its target group, Thai TikTok users who follow influencers, has no sampling frame, so probability sampling was not an option. Instead, an online questionnaire was circulated by convenience through social media channels, which means the sample carries no claim to represent Thai TikTok users as a whole. Inclusion rested on three conditions: informed consent, naming TikTok as the platform used most regularly, and complete answers to every measurement item. Of 321 responses received, two respondents declined consent and 210 named a platform other than TikTok, leaving 109 valid cases for analysis. The questionnaire was distributed without geographic restriction but did not record respondents' province or region, so the geographic spread of the sample could not be assessed. Two recommended rules for the minimum sample size in PLS-SEM were applied: the ten-times rule and the inverse-square-root method, which jointly placed the floor at roughly 100-110 cases for the most heavily predicted

from established, previously validated scales [29].

All constructs were measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Trustworthiness and expertise were each measured with five items adapted from Ohanian [7]. Attractiveness was measured with four items, combining physical-attractiveness items from Ohanian [7] with a social-attractiveness item adapted from Sokolova and Kefi [13]. Attitude toward the influencer was measured with four items adapted from Belanche et al. [10] and Silvera and Austad [18], and intention to purchase with two items adapted from Bi and Zhang [19]. Content validity was supported by adapting all items from validated scales, and a pilot test with thirty-seven respondents was conducted to refine item wording.

The hypotheses were tested using partial least squares structural equation modeling (PLS-SEM), which is well suited to predictive models with mediating paths [27]. The model was estimated with the *sempr* package, and path significance was assessed through bootstrapping with 5,000

subsamples. Analysis followed two stages: the measurement model was assessed first, followed by the structural model. Effect sizes were interpreted using Cohen's benchmarks of 0.02, 0.15, and 0.35 for small, medium, and large effects [30].

3. RESULTS AND DISCUSSION

The profile of the 109 respondents appears in Table 1. Two features stand out. The first is demographic concentration: 90.8% were aged 18-24, 78.0% were female, and 90.8% were students, with 71.6% holding a

bachelor's degree and 84.4% earning under 15,000 baht a month, a pattern typical of a student-heavy sample. The second is depth of engagement with the platform. Opening TikTok several times a day was the norm (89.0%), 39.4% followed more than 50 influencers, and buying on an influencer's recommendation was something 93.6% had done at least once. Read together, the two features mean the sample is a screened group of young, heavy TikTok users who actively follow influencers, and it should not be taken as a representative cross-section of Thai TikTok users.

Table 1. Profile of respondents (N = 109)

Characteristic	Category	n	%
Age	18-24	99	90.8
	35-44	8	7.3
	45-54	2	1.8
Gender	Female	85	78.0
	Male	24	22.0
Highest education	Secondary school or below	18	16.5
	Vocational or technical college	9	8.3
	Bachelor's degree	78	71.6
	Master's degree	4	3.7
Occupation	Student	99	90.8
	Full-time employee	8	7.3
	Business owner	1	0.9
	Part-time employee	1	0.9
Monthly income (baht)	Below 15,000	92	84.4
	15,000-30,000	10	9.2
	30,001-50,000	5	4.6
	50,001-100,000	2	1.8
TikTok use frequency	Several times a day	97	89.0
	Once a day	6	5.5
	Two to three times a week	2	1.8
	Once a week	1	0.9
	Less than once a week	3	2.8
Time on TikTok per day	Less than 30 minutes	10	9.2

	30 minutes to 1 hour	35	32.1
	1-2 hours	23	21.1
	2-3 hours	13	11.9
	More than 3 hours	28	25.7
Influencers followed	1-5	23	21.1
	6-10	25	22.9
	11-20	13	11.9
	21-50	5	4.6
	More than 50	43	39.4
Purchased on an influencer's recommendation	Yes	102	93.6
	No	7	6.4

All indicator loadings ranged from 0.864 to 0.948, exceeding the 0.70 threshold. Internal consistency was satisfactory, with Cronbach's alpha and rho_A between 0.856 and 0.959

and composite reliability between 0.933 and 0.970. Average variance extracted (AVE) ranged from 0.811 to 0.890, confirming convergent validity (Table 2).

Table 2. Measurement model: reliability and convergent validity

Construct	Items	Loadings	α	rho_A	CR	AVE
Trustworthiness (TR)	5	0.898–0.937	0.954	0.955	0.965	0.845
Expertise (EX)	5	0.893–0.936	0.957	0.957	0.966	0.852
Attractiveness (AT)	4	0.864–0.929	0.922	0.922	0.945	0.811
Attitude (ATTI)	4	0.935–0.948	0.959	0.959	0.970	0.890
Purchase intention (ITP)	2	0.935	0.856	0.856	0.933	0.874

Discriminant validity was assessed with the heterotrait-monotrait ratio of correlations (HTMT) [31]; Table 3 reports the full matrix with 95% bootstrap confidence intervals. Two pairs were high, attractiveness with

attitude (HTMT = 0.920) and attitude with purchase intention (HTMT = 0.885), but the inference-based criterion was met, as the upper bound of the 95% bootstrap confidence interval stayed below 1.00 for

every pair. The size of these two ratios still signals considerable conceptual closeness between the constructs involved, and it is

treated as a limitation when the mediation results are interpreted.

Table 3. HTMT ratios and 95% bootstrap confidence intervals

Construct pair	HTMT	2.5% CI	97.5% CI
TR - EX	0.801	0.680	0.890
TR - AT	0.758	0.593	0.870
TR - ATTI	0.849	0.753	0.910
TR - ITP	0.836	0.700	0.947
EX - AT	0.766	0.616	0.880
EX - ATTI	0.791	0.658	0.885
EX - ITP	0.788	0.636	0.915
AT - ATTI	0.920	0.830	0.976
AT - ITP	0.844	0.714	0.951
ATTI - ITP	0.885	0.781	0.984

Collinearity was examined through the variance inflation factor (VIF) at both levels of the model, and Table 4 reports the complete set of values. Within the structural model, the inner VIFs ranged from 2.388 to 4.136 and stayed below the common threshold of 5, with one exception: attitude in the purchase-intention equation reached 5.897, which edges past the conservative cutoff and is noted as a limitation. At the item level, the

outer VIFs ranged from 2.270 to 6.315. Several trustworthiness, expertise, and attitude items exceeded 5, which mirrors the very high internal consistency of these scales; since every construct is measured reflectively, closely correlated items are expected by design, and item-level collinearity does not carry the interpretational weight it would in a formative measurement model [27].

Table 4. Collinearity statistics (VIF)

Panel A: Inner VIF (structural model)

Predictor	ATTI equation	ITP equation
TR	2.780	3.503
EX	2.843	2.900
AT	2.388	4.136
ATTI	–	5.897

Panel B: Outer VIF (measurement items)

Item	VIF	Item	VIF
TR1	3.812	AT1	3.114
TR2	3.742	AT2	3.621
TR3	5.313	AT3	2.462
TR4	5.311	AT4	4.267
TR5	4.355	ATTI1	5.857
EX1	3.576	ATTI2	5.095
EX2	5.396	ATTI3	5.958
EX3	4.974	ATTI4	6.315
EX4	5.497	ITP1	2.270
EX5	5.273	ITP2	2.270

The structural model explained substantial variance, with R-squared of 0.830 for attitude toward the influencer and 0.693 for intention to purchase. Of the seven hypotheses, four were supported (Table 5, Figure 2). Trustworthiness significantly affected attitude (beta = 0.350, $t = 4.624$, $p < 0.001$, $f\text{-squared} = 0.259$; H1 supported) and purchase intention (beta = 0.244, $t = 2.432$, $p = 0.016$,

$f\text{-squared} = 0.055$; H5 supported). Attractiveness was the strongest driver of attitude (beta = 0.544, $t = 7.329$, $p < 0.001$, $f\text{-squared} = 0.728$; H3 supported) but did not significantly affect purchase intention directly (beta = 0.179, $p = 0.074$; H7 not supported). Attitude toward the influencer significantly predicted purchase intention (beta = 0.346, $t = 3.060$, $p = 0.007$, $f\text{-squared} = 0.066$; H4

supported). Expertise affected neither attitude (beta = 0.099, $p = 0.101$; H2 not supported) nor purchase intention (beta = 0.135, $p = 0.129$; H6 not supported), with very small effect sizes (f -squared = 0.020).

Table 5. Results of hypothesis testing

H	Path	β	t	p	f^2	Decision
H1	TR $\rightarrow$ ATTI	0.350	4.624	<.001	0.259	Supported
H2	EX $\rightarrow$ ATTI	0.099	1.436	.101	0.020	Not supported
H3	AT $\rightarrow$ ATTI	0.544	7.329	<.001	0.728	Supported
H4	ATTI $\rightarrow$ ITP	0.346	3.060	.007	0.066	Supported
H5	TR $\rightarrow$ ITP	0.244	2.432	.016	0.055	Supported
H6	EX $\rightarrow$ ITP	0.135	1.290	.129	0.020	Not supported
H7	AT $\rightarrow$ ITP	0.179	1.725	.074	0.025	Not supported

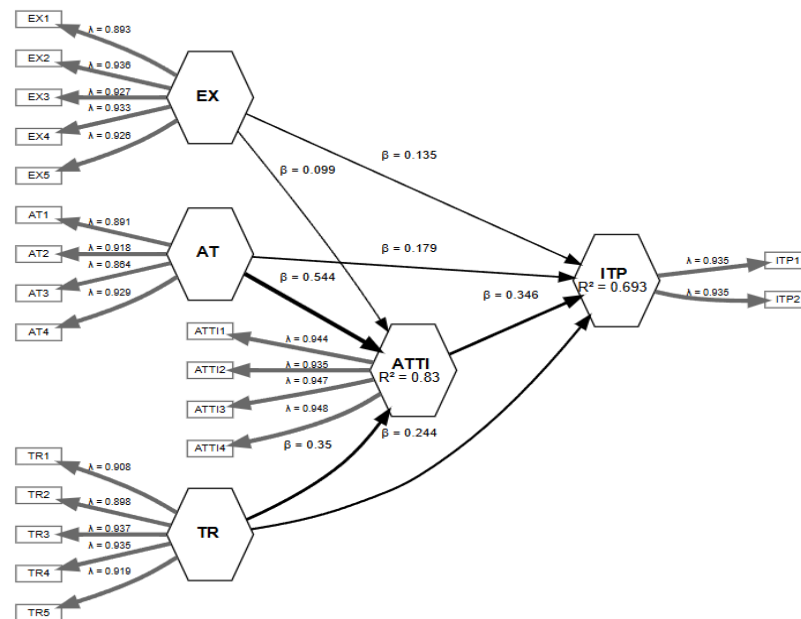


Figure 2. Estimated structural model with standardized path coefficients

Mediation analysis showed that attitude toward the influencer carried a significant indirect effect for trustworthiness (beta = 0.121, $p = 0.007$; partial mediation) and for attractiveness (beta = 0.189, $p = 0.007$; full mediation), but not for expertise (beta = 0.034, $p = 0.107$; no mediation).

Among the three credibility dimensions, attractiveness performed best, but in a specific way: it strongly shaped attitude toward the influencer while showing no direct effect on purchase intention. The three dimensions produced three different stories. Attractiveness

had the largest effect in the model, yet all of it flowed through attitude toward the influencer; there was no direct path to purchase intention. Prior work on charismatic communicators points the same way: their appeal transfers positive feelings into the audience's evaluation rather than acting on behaviour directly [11,24,25]. For trustworthiness the picture was broader. It raised purchase intention directly and, in parallel, worked through attitude, so a sincere influencer appears central to what makes product reviews effective for this audience [20,21]. And then there is expertise, which did nothing on either path despite carrying weight in research on other platforms [12,22]. The result is not isolated. On TikTok in Malaysia, trustworthiness and attractiveness raised the intention to purchase local cosmetics while expertise showed no significant effect [32]. A plausible reason lies in what TikTok is: short videos about entertainment, lifestyle, and beauty, watched by a young audience that seems to reward sincerity more than displays of in-depth knowledge. If so, credibility is not worth the same everywhere; its value moves with platform and content type. The mediation results support that reading, since credibility reached purchase intention mainly through the "overall evaluation of the influencer" in the audience's mind [17,19].

Age deserves a caveat of its own. Nine out of ten respondents were 18-24. The data therefore say nothing about how older users evaluate TikTok influencers, and with so few older respondents there was no basis for any meaningful subgroup comparison. It is plausible that older cohorts weigh the three dimensions differently. They

might, for example, put more value on demonstrated expertise, or on trust built up through longer purchase experience, and content that lands with a young audience may not travel across age groups. Whether the pattern found here extends beyond young users is an open empirical question. Answering it will take samples in which older age groups are properly represented.

4. CONCLUSIONS

This study asked two questions about influencer marketing on TikTok in Thailand. First, how do trustworthiness, expertise, and attractiveness, the three influencer characteristics drawn from source credibility theory, shape attitude toward the influencer and intention to purchase? Second, does attitude mediate these effects? The answers were not uniform across the three dimensions. Attractiveness drove attitude more strongly than anything else in the model. Trustworthiness reached both outcomes, influencing attitude and purchase intention alike. Expertise moved neither. Attitude toward the influencer, for its part, significantly predicted purchase intention and carried the effects of trustworthiness and attractiveness through to it.

Two theoretical points follow. The first is that on short-form video the three credibility dimensions are not interchangeable; how much each one matters depends on what the platform affords. The second concerns mechanism: credibility became intention here largely by way of attitude toward the influencer, which puts that attitude at the centre of the process. The practical reading is close behind. Brands choosing and briefing TikTok

influencers for young Thai audiences get more from authentic appeal and perceived trustworthiness than from displays of expertise, and selection criteria should reflect that. What ultimately drives purchase intention is the favourable attitude an influencer creates, so that attitude, rather than any list of credentials, is what deserves a brand's management attention.

Several limitations should be noted. The data are cross-sectional and drawn from a single self-report source, so common method variance cannot be fully ruled out; however, the differentiated pattern of findings, the non-significant effects of expertise and three unsupported hypotheses, is inconsistent with the uniform inflation that pervasive common method bias would produce. The sample was one of convenience, was modest in size (109 cases, near the calculated minimum for the model), and was heavily skewed toward young, female, student respondents, so the findings describe this segment of TikTok users rather than Thai TikTok users at large; region of residence was not recorded, leaving the geographic coverage of the sample unknown. Measuring purchase intention with two items is a further weakness. The construct showed acceptable reliability ($CR = 0.933$, $AVE = 0.874$), but two items cover its conceptual domain only narrowly, and results involving this construct deserve corresponding caution. The strong overlap between attractiveness and attitude, together with the inner VIF of 5.897 for attitude in the purchase-intention equation, likewise calls for careful reading of the mediation findings. Future research could use temporally separated or multi-source

designs, larger samples that include older age groups and record where respondents live, purchase-intention scales of at least three or four items, and behavioural rather than stated outcomes.

5. ACKNOWLEDGMENTS

The authors thank their families for every opportunity and for support that never wavered. The first author is grateful to his university for the chance to pursue doctoral study, which shaped his understanding of what sound research requires, and to his advisor, whose knowledge and patient guidance made this work possible. Lastly, he thanks himself, for continuing to fight for himself, for his students, and for the university.

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A Comparative Analysis of Boutique Hotel Characteristics and Service Quality Standards: Perspectives from Managers and Guests Vicheth Nara

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ABSTRACT

The purpose of this paper is to examine the perspectives of boutique hotel managers and guests regarding whether they share a similar understanding of the characteristics and service quality of boutique hotels. A qualitative research method utilizing semi-structured interviews was adopted to gather data from boutique hotel managers and international tourists who had previously stayed or were currently staying in boutique hotels in Siem Reap. Furthermore, the collected interview data were analyzed using the constant comparative analysis method. The findings indicated that both boutique hotel managers and guests generally share similar perceptions of boutique hotel characteristics and service quality in Siem Reap, although they express their views in different ways. The results also suggest that boutique hotel managers have a strong understanding of their guests' needs and expectations. Nevertheless, some misunderstandings between managers and guests still exist, indicating the need for further improvement. In particular, boutique hotels should place greater emphasis on human resource development and prioritize local design elements in their hotel operations.

Keywords: Boutique hotel, Characteristic, Hotel Manager Perspective, Guest Perspective, Service quality

1. Introduction

Cambodia is known as one of the emerging tourist destinations in ASEAN, attracting visitors with its diverse attractions and rich cultural heritage. The tourism industry serves as a major contributor to the country's economy and is expected to continue playing a vital role in national economic development. In 2025, the number of international tourist arrivals in Cambodia reached 6.7 million visitors, injecting 3.6 billion USD into the country's economy, according to Teng (2025). Due to the continuous growth of both international and domestic tourism, along with the significant tourism expenditure contributing to the Cambodian economy, many Cambodian and foreign investors have taken the opportunity to invest in the hotel industry in major tourist destinations such as Phnom Penh, Kampot, and especially Siem Reap, the ancient city of Cambodia. Consequently, a wide range of accommodation types can be found in Siem Reap, including luxury hotels, business hotels, budget hotels, serviced apartments, resort, and boutique hotel.

A boutique hotel is a type of accommodation characterized by its unique architectural design, limited number of rooms, and personalized services offered to guests as part of a small hospitality business (Anhar, 2001; Buhagiar et al., 2024). With the growing global popularity of boutique hotels, particularly in the United States and the United Kingdom, where the first boutique hotels were established, this trend has significantly influenced the development of the Cambodian accommodation industry. However, as the number of boutique hotels in Siem Reap continues to increase, competition between existing and newly established boutique hotels has become increasingly intense. Therefore, hoteliers must be strategic in differentiating their products and services from competitors while also understanding customers' perceptions, expectations, and the

constantly changing travel trends. At the same time, due to the absence of a universally accepted and officially recognized definition of a “boutique hotel,” it is still challenging to clearly distinguish its defining characteristics and to determine which properties genuinely fall under this category. Consequently, this ambiguity can result in customer confusion and dissatisfaction with boutique hotels.

Although previous studies have explored boutique hotel characteristics and service quality, the majority have examined these topics from only one perspective, either that of guests or hotel managers, rather than comparing both viewpoints within the same context (Dedeoğlu & Demirer, 2015). In addition, existing research has been conducted primarily in developed countries (Lim & Endean, 2009), leaving a noticeable lack of evidence from developing nations, particularly those in Southeast Asia. This gap is significant because the hotel industry in many developing countries is expanding rapidly, yet limited research has investigated whether managers' perceptions and priorities regarding service quality align with guests' actual experiences. Such discrepancies may negatively affect guest satisfaction and the overall competitiveness of boutique hotels (Dedeoğlu & Demirer, 2015).

Cambodia, especially Siem Reap, provides an appropriate setting for addressing this research gap due to its rapid growth in the boutique hotel sector and its importance as a leading tourism destination in a developing economy (Teng, 2025). Furthermore, the findings are expected to provide practical insights not only for Cambodia but also for other developing countries with similar tourism and economic conditions. By examining and comparing the perspectives of both hotel managers and guests, this study extends the existing literature by providing empirical evidence from an emerging Southeast Asian tourism market, thereby addressing

a context that has received relatively limited attention in boutique hotel and service quality research.

1.1. Research objectives

1. To explore the understanding of boutique hotel characteristics among boutique hotel managers and guests
2. To compare the perspectives of boutique hotel managers and guests regarding service quality requirements in selected boutique hotels
3. To examine the challenges faced by boutique hotels in meeting guests' service quality expectations.
4. To identify the factors that influence guest satisfaction and dissatisfaction during their stay in boutique hotels

1.2. Literature Review

1.2.1. The characteristics of a boutique hotel

The term “boutique hotel” originated in the 1980s and was introduced by Steve Rubell and Ian Schrager, the owners of the Morgans Hotel in New York City (Blacklane Team, 2025). However, because there is still no officially recognized definition of a boutique hotel, many researchers, scholars, and organizations have proposed their own definitions and identified different characteristics of this type of accommodation based on their studies and experiences. According to Anhar (2001), a boutique hotel should contain no more than 150 rooms, provide personalized services, and may be located in various settings such as city centers, resorts, or forest areas. Similarly, Siggs (2004) and Ismail et al. (2014) suggested that boutique hotels should create a homely atmosphere and offer personalized services while incorporating heritage buildings and local culture into their design concepts. Srinivas et al. (2013) described boutique hotels as accommodations with modern and stylish designs,

intimate guest services, and urban locations. In the same way, Potocakova (2015) defined boutique hotels as city-center hotels featuring unique heritage designs and high service quality. Furthermore, Day et al. (2013) identified boutique hotels through characteristics such as customized services, stylish design, advanced technology, and modern in-room amenities. Likewise, Horner (2005) and Erkutlu (2006) viewed boutique hotels as small-scale accommodations with modern styles and elegant furniture that strongly emphasize personalized service. In addition, Dev et al. (2005) highlighted upscale services, mid-range pricing, and modern lifestyle amenities as key characteristics of boutique hotels.

Based on the definitions and characteristics of boutique hotels discussed by various scholars, there are both similarities and differences among their perspectives. These similarities and differences likely arise from differences in research contexts, geographical locations, and the individual perceptions and experiences of researchers. Overall, boutique hotels are generally aimed at creating a homely atmosphere, fostering close guest relationships, delivering high-quality service, and offering distinctive experiences through unique design, architecture, and personalized services.

1.2.2. Service quality

Service quality is a concept that is difficult to define and measure precisely because it largely depends on consumers' evaluations of whether the service meets their expectations. To better understand the concept, it is necessary to examine the meanings of “service” and “quality” separately. Blois (1974) defined service as activities offered for sale that aim to provide satisfaction and benefits to customers. Meanwhile, quality refers to the ability to meet or exceed consumer expectations (Ekinci, 2008). Similarly, Juran (1988) defined quality as the

features of a service that fulfill consumers' expectations and lead to customer satisfaction.

In general, service quality is evaluated individually by consumers based on their personal experiences with the service. Therefore, perceptions of service quality may vary from one person to another depending on whether the service fulfills their needs, wants, and expectations. Furthermore, A. Parasuraman et al. (1985) described service quality as the degree and direction of the gap between customers' expectations and their actual perceptions of the service received.

2. Methodology

A qualitative research design was adopted in this study to collect the required data. Semi-structured interviews were conducted to obtain information from boutique hotel managers and international tourists who had previously stayed or were currently staying in boutique hotels in Siem Reap. A total of 18 open-ended questions were developed and organized into two sections, consisting of nine questions for boutique hotel managers and nine questions for tourists. In terms of sample size, the study included five boutique hotel managers and 11 international tourists in Siem Reap.

For this study, the researcher selected standard boutique hotels with three-star and four-star ratings because these types of boutique hotels are highly popular and widely available in Siem Reap. Consequently, five boutique hotels were chosen based on their hotel category, star rating, price range, and the availability of hotel managers to participate in the interviews.

Moreover, 11 international tourists were interviewed at locations including Siem Reap Angkor International Airport, Old Market, Night Market, Angkor Wat, and five boutique hotels. The airport was chosen because it is a major gathering place for

international tourists, who often have sufficient time to answer interview questions in detail. In addition, Old Market and the surrounding areas around Night Market were selected due to their popularity among tourists and the high concentration of boutique hotels located nearby. Furthermore, the constant comparative analysis method was employed to analyze the data collected from the interviews.

Participants were selected using purposive sampling, which allowed the researcher to specifically target boutique hotel managers with direct decision-making responsibility over service quality, and international tourists who had experience staying in boutique hotels in Siem Reap, ensuring that all participants could provide information responses to the research objectives. Data collection was terminated after thematic saturation was achieved, meaning that interviews stopped once subsequent interviews with both managers and tourists ceased to generate new themes or codes. Therefore, the final sample of five managers and 11 tourists reflects the point at which the range of perspectives on boutique hotel characteristics, service quality, challenges, and guest satisfaction had been sufficiently captured, rather than a predetermined target sample size.

3. Results and Discussion

This study seeks to investigate whether boutique hotel managers and guests share a common understanding of the characteristics and service quality of boutique hotels in Siem Reap. A comparative approach was used to examine similarities and differences between the two groups, focusing on hotel characteristics, service quality expectations, challenges in service delivery, and the key factors that influence guest satisfaction and dissatisfaction.

3.1. The characteristics of a boutique hotel

The characteristics of boutique hotels have been defined by many scholars worldwide, including elements such as size, location, design, service, and overall quality provided, as noted by Mun Lim and Endean (2009). In this study, hotel managers described boutique hotel characteristics in line with these five dimensions; however, they placed greater emphasis on service delivery compared to other aspects. All respondents identified service delivery as the main priority in their boutique hotels and regarded it as the key driver of business success. They further explained that excellent service quality plays a crucial role in impressing guests and enhancing their satisfaction. In contrast, when service quality fails to meet guests' expectations, guests tend to perceive the overall hotel experience negatively, even if the hotel offers outstanding room design or a prime location. As a result, the entire service and product offering may be judged as below standard.

"The combination of convenient location, distinctive design, excellent service, and high-quality facilities is what defines a successful boutique hotel." Manager 3

"A boutique hotel is not only about small size and unique design, but also about providing high-quality service that makes guests feel special. For our boutique hotel, excellent service is the most important selling point." Manager 5

Among boutique hotel guests, most respondents tend to differentiate boutique hotels from other types of accommodation primarily based on hotel design rather than service delivery. Many of them described boutique hotels as small-scale properties with unique, modern, and stylish designs. They also associated boutique hotels with strong personality and aesthetic identity, often highlighting their distinctive architectural and interior design features. In addition, guests commonly viewed boutique hotels as offering

excellent and personalized service, and being located either in city centers or suburban areas. Overall, their perceptions suggest that design plays a more dominant role than service delivery in how they recognize and define boutique hotels.

"I usually recognize a boutique hotel by its unique, modern, and stylish design." Tourist 2

"For me, boutique hotels are usually in good locations like city centers and have a distinctive design that makes them different." Tourist 5

"I see boutique hotels as small, modern places with personalized service, especially a unique design." Tourist 4

After comparing the perspectives of hotel managers and hotel guests, the findings reveal that both groups have a broadly similar understanding of boutique hotel characteristics. However, differences exist in the way they describe and emphasize these characteristics. Hotel managers tend to focus primarily on personalized service as the most important feature and highlight that boutique hotels can be located in various settings without restriction. In contrast, hotel guests place greater emphasis on unique room design and often associate boutique hotels specifically with city-center locations.

This pattern of divergence, in which hotel managers place greater weight on service delivery while guests emphasize the tangible, visual aspects of the property, is consistent with prior comparative research on hospitality stakeholder perceptions. Likewise, Dedeoğlu and Demirer (2015) established that managers and customers do not evaluate the same service dimensions in the same way, since they occupy different positions within the service encounter. These findings collectively support the argument that boutique hotel management and marketing strategies should not assume that

managers' and guests' understandings of what makes a boutique hotel are automatically aligned.

3.2. Service quality requirements of a boutique hotel

Boutique hotel managers offered more detailed and systematic explanations of service quality requirements compared to guests. They generally classify service quality into two main dimensions: tangible and intangible aspects. For tangible elements, managers pointed to room design, the quality of food, and the standard of hotel facilities. For intangible aspects, they emphasized staff interactions, the quality of service delivery, the overall hotel atmosphere, and the relationship between employees and guests. In contrast, guests tended to describe service quality requirements more subjectively, largely based on their individual experiences, feelings, and personal expectations. Their responses mainly focused on employee performance and psychological comfort or security during their stay. Only a small number of guests associated service quality with physical aspects such as room design, facilities, or location.

"Regarding service quality, we place strong emphasis on employee service delivery and how staff respond to guest needs." Manager 1

"Our service quality combines both physical aspects like quality facilities and food, plus non-physical aspects like staff behavior with our customers." Manager 2

"I feel satisfied when employees provide respectful service and respond quickly to my needs." Tourist 10

"For me, service quality mainly depends on how friendly, helpful, and attentive the hotel staffs are." Tourist 12

"Psychological comfort and feeling welcomed and safe are very important parts of my

hotel experience, as well as good facilities and location." Tourist 7

When comparing both perspectives, the findings reveal several similarities in their views on service quality requirements in boutique hotels in Siem Reap. Both hotel managers and guests highlighted key elements such as unique room design, strong employee interaction, high service performance, and well-maintained hotel facilities as important aspects of service quality. However, some differences were also identified between the two groups. Hotel managers placed greater emphasis on factors such as high-quality food and a well-designed hotel environment, while guests focused more on psychological security, including feelings of safety, personal security, and privacy during their stay.

This finding aligns with earlier service-quality gap research, which has consistently shown that hotel managers and guests do not weigh service quality dimensions identically. Previous literature reported that customers, employees, and managers in the hotel industry differ significantly in how they rate the importance and performance of specific service quality dimensions, with employees and managers tending to emphasize operational and tangible aspects, while customers place greater weight on the emotional and experiential aspects of the encounter (Crossman, 2024; Dedeoğlu & Demirer, 2015). The present findings extend this line of research to the boutique hotel segment, indicating that even in a small-scale, personalized hospitality setting, the psychological and security-related dimensions of service quality that matter most to guests are not always the dimensions most emphasized by managers.

3.3. Service quality challenges of a boutique hotel

Based on the responses of boutique hotel managers regarding operational challenges, the

findings indicate that these challenges can be classified into two categories: internal and external factors. Internal challenges refer to issues arising within the hotel or those under managerial control. These include the poor physical condition of hotel buildings, high employee turnover, staffing limitations, language barriers, technical difficulties, and budget constraints that restrict improvements in service quality and operations. In contrast, external challenges are those influenced by guests or other outside conditions. These include unethical guest behavior, high and sometimes unrealistic guest expectations. Overall, these challenges represent key obstacles that hinder boutique hotels from fully meeting guest expectations and make it more difficult for them to continuously improve their service quality.

"Employee turnover and staffing limitations are major internal issues that make it difficult to maintain consistent service. Also, limited budgets affect our ability to improve service quality." Manager 1

"We often deal with guests who have very high expectations that are difficult to meet, and some guests behave unethically, which creates additional pressure for our staff." Manager 4

"Some of our customers couldn't speak English, and our staffs couldn't speak our customers' language, that's why some misunderstandings happened." Manager 2

In addition, hotel guests reported several challenges related to service quality in boutique hotels. These include language barriers between guests and hotel employees, which often create communication difficulties during their stay. Guests also expressed concerns about the quality of hotel facilities, which in some cases did not meet their expectations. Furthermore, issues related to employee behavior were highlighted, including

instances of unprofessional conduct and a lack of sufficient skills among staff. Some guests also mentioned negative experiences caused by the behavior of other unethical guests, which affected their overall comfort. Another important issue raised was the inconsistency between online promotional images and the actual hotel rooms. Several guests stated that the photos shown on online travel agencies (OTAs) appeared perfect, but upon arrival, the actual rooms did not match the images, leading to disappointment and dissatisfaction.

"I experienced situations where employees were not well-trained or sometimes could not speak English well. I also experienced a noisy guest next door that disturbed me all night." Tourist 8

"I felt disappointed because the hotel room looked perfect in OTA photos, but in reality, it was very different." Tourist 3

"The quality of some hotel facilities was not as good as I expected during my stay. The facilities looked old and did not match the price I paid for the room." Tourist 6

After comparing both perspectives on the challenges related to service quality in boutique hotels, the findings indicate that hotel managers tend to provide more detailed explanations of the challenges they face, including both internal and external factors, due to their extensive experience in the hospitality industry. In contrast, when discussing challenges, most guests mainly focus on issues related to service delivery by hotel employees. Only a small number of guests mentioned other concerns, such as the discrepancy between online images of hotel rooms and their actual conditions upon arrival.

The internal challenges reported by boutique hotel managers in this study, particularly

employee turnover, staffing shortages, and budget limitations, are consistent with the findings of Zhao et al. (2025) and Ali et al. (2021). Both studies identified budget constraints, employee attitudes, insufficient mentoring, and increasing customer expectations as major obstacles to improving service quality. Likewise, Wen et al. (2020) found that front-line hotel employees' turnover intentions are strongly associated with role stress and burnout, with high turnover subsequently reducing the consistency of service delivery. This aligns with this study, where managers indicated that frequent employee turnover makes it difficult to maintain consistent service quality. The similarity of these findings across different hotel categories and geographical settings suggests that staffing-related issues are a widespread and structural challenge within the hospitality industry, rather than a problem unique to boutique hotels in Siem Reap.

3.4. Guest satisfying/dissatisfying factors in a boutique hotel

All managers stated that it is difficult to clearly separate the factors that contribute to guest satisfaction and dissatisfaction, as these elements are closely interconnected. However, among all factors, they emphasized that employees are the most critical element in ensuring customer satisfaction, while also being a potential source of dissatisfaction if service delivery is inadequate. In addition to employee performance, managers identified several other important factors that influence guest satisfaction. These include the hotel environment, overall service performance, room design, technology usage, quality of hotel facilities, pricing, the behavior of other guests, and the emotional state of guests during their stay.

"Among all factors, employees are the most essential element in creating guest satisfaction in boutique hotels. At the same time,

employees can also become the main source of guest dissatisfaction if service delivery goes wrong." Manager 5

"Room design, technology, price, and the quality of facilities are also key factors that affect how guests perceive our service." Manager 4

"Guest emotions sometimes are influenced by a combination of all service offer by our hotels and their own emotions. The behavior of other guests can also impact the overall experience and satisfaction level." Manager 1

Guests identified satisfaction factors based on how pleased they were with what they received from the hotel, including personalized service, excellent room design, a pleasant environment, reasonable pricing, and positive employee interactions. These elements were associated with positive experiences that met or exceeded their expectations. Similarly, guests identified dissatisfaction factors based on experiences that fell below their expectations or resulted in negative experiences during their stay. These included poor employee behavior, language barriers, overly simple room design, and slow service delivery.

"Factors that make me happy with the hotel are good room design, a comfortable environment, and excellent service. And I am not happy when the service I receive is below what I expected before arriving." Tourist 11

"A good price that matches the service quality is an important factor in my satisfaction. Also, good employee behavior greatly increases my overall satisfaction with the hotel." Tourist 10

"What I hate the most is when unprofessional service is delivered by unethical employees. Some hotel employees I met offer very slow service and make excuses all the time. What

I describe above are the main reasons I feel unhappy with a hotel.” Tourist 1

Even though the guests described separately the factors that made them satisfied or dissatisfied with the hotel, the answers they gave were the same as those the hotel managers described.

The pivotal role of employees in influencing both guest satisfaction and dissatisfaction has been widely recognized in the service quality literature. The SERVQUAL framework developed by Parasuraman et al. (1985) identifies responsiveness and assurance, both of which are largely conveyed through employee–guest interactions, as fundamental dimensions that shape customers’ evaluations of overall service quality. Likewise, Ismail et al. (2014) and Lee-Anant and Rungreang (2024) highlighted that personalized service provided by hotel staff is a distinguishing characteristic of boutique hotels and a key contributor to guest satisfaction. The alignment between the present findings and previous research suggests that, irrespective of a boutique hotel’s physical design or geographic location, the quality of interactions between employees and guests remains the most influential factor in shaping guests’ overall satisfaction or dissatisfaction.

4. Conclusion

The study found that both boutique hotel managers and guests in Siem Reap generally share a similar understanding of boutique hotel characteristics and service quality (Figure 1), although they express their views in different ways. Hotel managers tend to describe these aspects holistically, drawing on their extensive knowledge and long-term experience in the hospitality industry. In contrast, hotel guests describe them in a more segmented way, based on individual components, due to their more limited experience

and exposure during their hotel stays. The findings also indicate that boutique hotel managers in Siem Reap have a strong understanding of customer needs and expectations. However, some level of misunderstanding between managers and guests still exists, suggesting the need for further improvement. In particular, hotels should invest more in human resource development and place greater emphasis on incorporating local Khmer design as a key priority. Overall, understanding customer needs and expectations is essential for achieving competitiveness and ensuring long-term business sustainability in the boutique hotel industry. This study provides insights into guest needs and expectations that can assist boutique hotel managers in improving service quality and developing more effective marketing strategies.

During the research process, the researcher encountered several limitations. First, there is limited literature available on the service quality of boutique hotels, as most previous studies have focused on luxury hotels due to their greater popularity, while boutique hotels have only gained attention in the past decade. Second, this study was conducted only in Siem Reap, which limits the generalizability of the findings to other cities. Differences in population, geography, and culture may influence hotel perceptions and experiences in other locations. Furthermore, the findings are based solely on the perspectives of boutique hotel managers and guests regarding characteristics and service quality in Siem Reap. Therefore, future research is recommended to compare the service quality of boutique hotels with other types of hotels. Such studies would provide more comprehensive insights and help guests make more informed decisions when choosing between boutique hotels and other accommodation types for their travel needs.

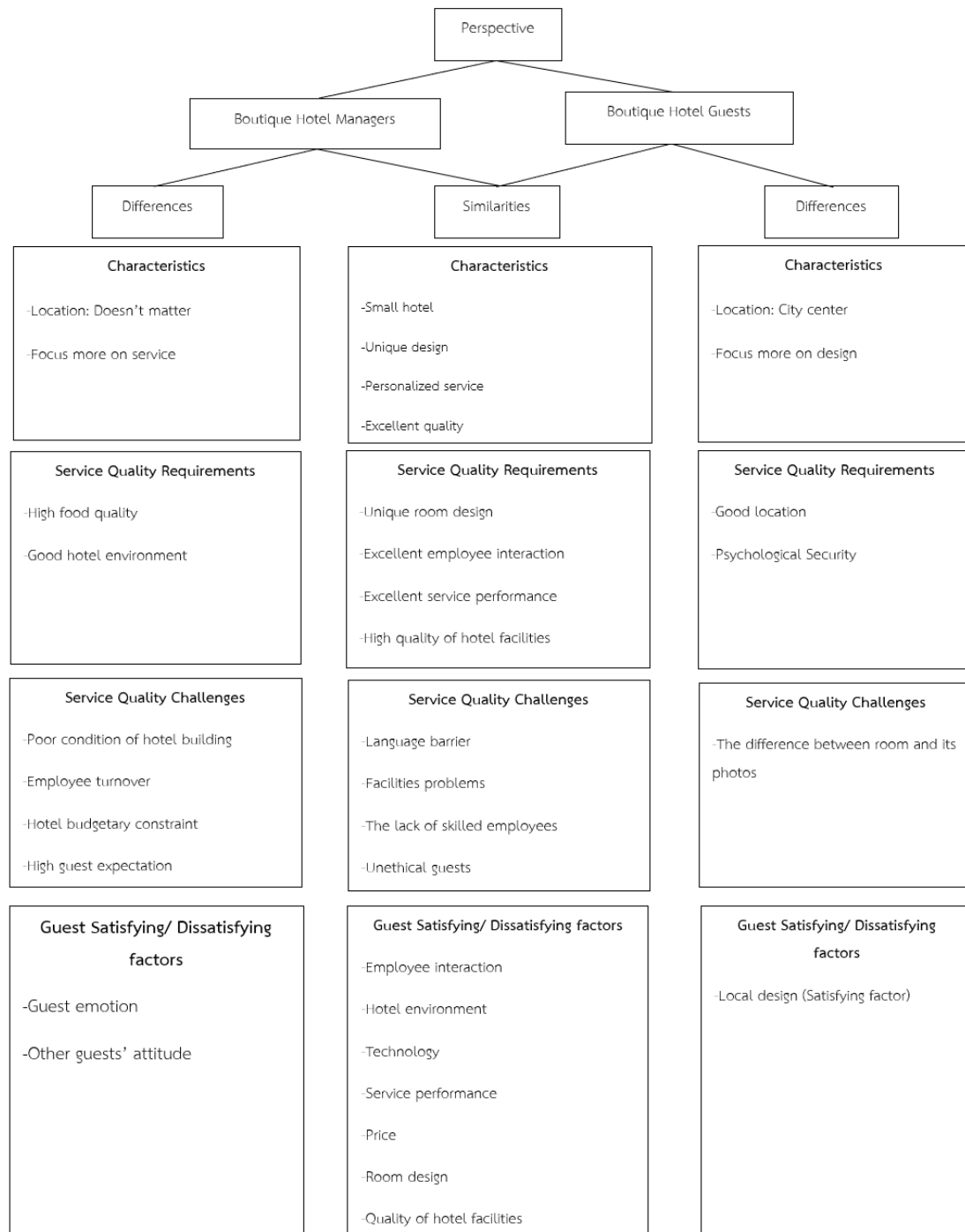


Figure 1: Key findings from the perspective of boutique hotel managers and guests

5. Acknowledgment

The author would like to sincerely thank the boutique hotel managers and tourists who generously participated in this study. Their

valuable time, insights, and cooperation were essential to the successful completion of this research.

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Tasting through the screen: media content quality, perceived media influence, and tourists' attitudes towards food tourism in Bangkok, Thailand

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ABSTRACT

Digital media now stand between the tourist and the table, yet little is known about how the quality of food-related content translates into the attitudes that sustain its use. Drawing on the elaboration likelihood model and the information adoption model, this study examines whether the perceived quality of media content shapes tourists' attitudes towards using online media for food tourism, and whether perceived media influence carries that effect. Survey data were collected from 386 Thai and international tourists in Bangkok and analyzed with regression-based mediation analysis (PROCESS Model 4, 5,000 bootstrap resamples), complemented by partial least squares structural equation modeling. Content quality exerted a strong positive effect on perceived media influence ($\beta = .741$), which in turn predicted media-use attitude and satisfaction ($\beta = .573$); the direct quality–attitude path remained significant ($\beta = .312$). Perceived influence partially mediated the quality–attitude relationship (standardized indirect effect = .425, 95% CI [.316, .533]), and the model explained 69.1% of the variance in media-use attitude. The findings extend information adoption research into gastronomy tourism and indicate that credible, accurate, and visually engaging content—rather than volume of exposure—is the lever through which destination marketers can convert screen time into culinary travel. The implications for destination marketing organizations, content creators, and platform strategy in Bangkok's food-tourism economy are discussed.

Keywords: food tourism, social media, information adoption, media content quality, mediation analysis, Bangkok

1. INTRODUCTION

Food has moved from the periphery of travel to its center. For an increasing share of visitors, what and where they will eat is decided before any monument or museum is included in the itinerary, and the meal itself has become the attraction rather than its accompaniment [1]. Bangkok occupies a privileged position in this economy of taste. The city's street-food culture is a recurring motif in global gastronomy rankings and travel journalism, and culinary experiences

feature prominently in Thailand's national tourism positioning.

The route to the table, however, now runs through a screen. Tourists encounter destinations as photographs, short videos, and reviews long before they encounter them as places, and electronic word-of-mouth has become one of the most consequential sources of information in travel decision-making [2,3]. Food is arguably the most mediatized of all tourism products: it is visual, shareable, and inexpensive to

sample, which makes platforms such as Facebook, Instagram, and YouTube, as well as review communities such as Wongnai, Pantip, and TripAdvisor, the natural arenas in which culinary reputations are made. Whether the content circulating in that arena actually changes what tourists do—and how they come to regard the media they rely on—is a question of direct commercial and theoretical interest.

Existing research offers only a partial answer. Studies of social media and destination choice typically treat influence as a uniform outcome and pay limited attention to the qualities of the content that produces it; Tham et al. [3] show that such influence is strongly contingent on context. The information adoption tradition, by contrast, specifies the mechanism—argument quality operating through perceived usefulness towards adoption [4,5]—but has rarely been carried into gastronomy tourism, and seldom in South-East Asian settings. What remains untested is the chain that matters most to practitioners: does better content produce a stronger sense of influence, and does that sense of influence cultivate the favorable attitudes that keep tourists returning to these channels?

This study addresses that gap. Using survey data from 386 Thai and international tourists, it models the relationships among media content and format quality (MCC), perceived media influence on food-travel decisions (MIN), and media-use attitude and satisfaction (MSA). Three contributions

follow. First, the study extends the elaboration likelihood model and the information adoption model into the food-tourism domain, treating media-use attitude as the downstream consequence of adoption rather than stopping at intention. Second, it quantifies the mediating role of perceived influence, showing that content quality works chiefly, but not exclusively, through it. Third, it offers destination marketers in Bangkok evidence on which content properties—credibility, accuracy, visual appeal—are worth their investment.

The remainder of the paper proceeds as follows. Section 2 develops the conceptual framework and hypotheses. Section 3 describes the data and method. Section 4 reports the results, and Section 5 discusses their theoretical and managerial implications, followed by the limitations and conclusion.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Food Tourism in a Mediatized Marketplace

Food tourism denotes travel in which the consumption, appreciation, or experience of food is a primary motivator [1]. The sector rewards destinations that can convert culinary distinctiveness into visitation, and Bangkok's street markets, Chinatown food stalls, and night bazaars have proven especially convertible. However, culinary capital is perishable: it must be continuously displayed to be

consumed, and display now happens on social platforms. User reviews, influencer videos, and destination campaigns compete for the same scarce attention, and the tourist's impression of a city's food scene is assembled largely from this mediated mosaic. Understanding how the properties of that content register with tourists is therefore not a peripheral media question but a core marketing one.

2.2 Theoretical Anchors: Elaboration Likelihood and Information Adoption

Two complementary frameworks specify how mediated information becomes behavioural influence. The elaboration likelihood model [6] distinguishes between a central route, in which message recipients scrutinize argument quality, and a peripheral route, governed by cues such as attractiveness. The information adoption model [4] extends this logic to computer-mediated settings: argument quality and source credibility shape perceived usefulness, which in turn determines whether information is adopted. Erkan and Evans [5] extended the model to social media, showing that the quality, credibility, and usefulness of electronic word-of-mouth jointly drive consumers' information adoption and subsequent purchase intentions. Applied to food tourism, the frameworks imply a sequence: tourists who judge food-related content as well-crafted and trustworthy should perceive it as genuinely influential in their travel decisions,

and repeated experiences of useful influence should consolidate into a favorable attitude towards the media themselves.

2.3 Media Content and Format Quality

Content quality in this study spans the visual and informational properties of food-tourism media: the attractiveness and aesthetic quality of images, the credibility of the information conveyed, its concision and accessibility, and its factual accuracy. These properties correspond to argument quality and peripheral visual cues simultaneously—food content persuades through the eye as much as through the proposition. Filieri and McLeay [7] demonstrate that information quality dimensions predict travelers' adoption of online reviews; in the culinary domain, where the product cannot be tasted remotely, the burden carried by imagery and credible description is heavier still. Tourists who find content attractive, credible, and accurate should accordingly experience it as influential when choosing where to eat and travel, and the same judgment of quality should color their overall evaluation of using such media. Hence:

H1. Media content and format quality positively affect perceived media influence on food-tourism decisions.

H3. Media content and format quality positively affect attitude towards and satisfaction with using online media for food tourism.

2.4 Perceived Media Influence and Media-Use Attitude

Perceived media influence captures the tourist's acknowledgment that online media, reviews, and advertising genuinely shape their food-travel decisions—the experiential analog of information adoption. When adoption is rewarding, the user's evaluation of the channel improves: satisfaction with platforms and a positive attitude towards consulting them again are the natural sediment of repeated useful influence [2,5]. The information adoption logic further implies that quality does not act

2.5 Conceptual Model

Figure 1 summarises the hypothesized model: content quality drives perceived influence (H1), perceived influence drives media-use attitude (H2), quality retains a direct path to attitude (H3), and the indirect path through influence constitutes the mediation hypothesis (H4).

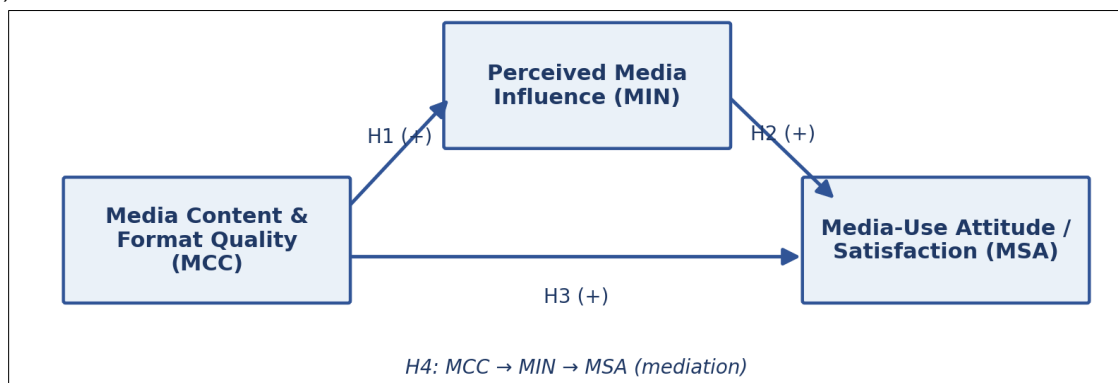


Figure 1. Conceptual Model

3. METHODOLOGY

3.1 Design, Sample, and Procedure

A cross-sectional questionnaire survey was administered to Thai and international tourists who had experienced food-related travel in Bangkok. Data were

on attitude only directly; much of its effect should travel through the experience of influence itself. These arguments yield the remaining hypotheses:

H2. Perceived media influence positively affects attitudes towards and satisfaction with using online media for food tourism.

H4. Perceived media influence mediates the relationship between media content quality and media-use attitude and satisfaction.

gathered in two collection waves using identical items, yielding a pooled sample of 386 after screening. Participation was voluntary and anonymous, and respondents were informed that the data would be used solely for research. The sample comfortably exceeds the inverse-square-root requirement

for detecting minimum path coefficients of about .15 at the 5% level [8], as well as the conventional 10-times rule.

Table 1 profiles the sample. Women constituted the majority (58.5%), and two-thirds of respondents were aged 26–45. Half were single, and private-company employment was the most common

occupation. Most respondents reported spending up to 5,000 THB per food-related search or restaurant visit.

Table 1. Sample profile (n = 386; five missing values on spending). Time online: 31.6% searched food content 1–2 times per week, and 34.2% 1–2 times per month; viewing photographs of attractions was the most common online activity (44.3%).

Characteristic	Category	n	%
Gender	Male	144	37.3
	Female	226	58.5
	Other	16	4.1
Age	25 or younger	58	15.0
	26–35	147	38.1
	36–45	118	30.6
	46–55	48	12.4
	Over 55	15	3.9
Marital status	Single	195	50.5
	Married/civil partner	173	44.8
	Divorced/separated	13	3.4
	Widowed/other	5	1.3
Occupation	Government/state enterprise	41	10.6
	Private company employee	146	37.8
	Homemaker	124	32.1
	Business owner	68	17.6
	Other	7	1.8
Spending per food search/visit	≤3,000 THB	111	28.8
	≤5,000 THB	168	43.5
	≤10,000 THB	57	14.8
	More than 10,000 THB	19	4.9
	Other/unspecified	26	6.7

3.2 Measures

All constructs were measured reflectively on a 7-point Likert scale (1 =

strongly disagree, 7 = strongly agree). Media content and format quality (MCC) comprised six items covering the attractiveness and

aesthetics of imagery, the influence of pictures on destination choice, and the credibility, concision, and accuracy of content. Perceived media influence (MIN) comprised five items on the influence of online media, advertising, and reviews on food-travel decisions. Media-use attitude and satisfaction (MSA) comprised seven items on satisfaction with using specific online media for food-tourism information: Facebook, Instagram, web pages (Wongnai), TripAdvisor, Pantip, YouTube, and Twitter/X. Content validity was established before fieldwork through an expert panel using the index of item-objective congruence (IOC), with items retained only when they met the conventional threshold.

3.3 Analytical Approach

Analyses were conducted in IBM SPSS. After descriptive and reliability analyses, the hypothesized paths were estimated using ordinary least squares regression, and the mediation hypothesis was tested with the PROCESS macro (Model 4) using 5,000 percentile bootstrap resamples [9]. Sampling adequacy and dimensionality were examined through principal component analysis with the Kaiser–Meyer–Olkin statistic and Bartlett’s test. Common method variance was probed with the single-factor test [10]. A complementary partial least squares structural equation model (PLS-SEM), recommended for prediction-oriented

composite models [11], is reported in Section 4.5.

4. RESULTS

4.1 Preliminary Analyses

Sampling adequacy was excellent ($KMO = .954$), and Bartlett’s test of sphericity was significant, $\chi^2(153) = 4,718.51$, $p < .001$, confirming the factorability of the 18-item correlation matrix. Principal component analysis extracted a dominant first component accounting for 54.2% of the total variance. Because a single factor exceeded half of the common variance, common method variance cannot be ruled out; procedural remedies—anonymity, separation of construct blocks, and neutral wording—were applied at the design stage, and the limitation is acknowledged in Section 6 [10].

4.2 Reliability

Internal consistency was satisfactory for every scale (Table 2): $\alpha = .812$ for MCC, .883 for MIN, and .923 for MSA, with an overall instrument alpha of .948. One MCC item (attractiveness of images) showed a weak corrected item–total correlation (.205; alpha-if-deleted .845); it was retained for the regression analyses to preserve the instrument’s content coverage, and its behavior is re-examined in the PLS-SEM measurement model (Section 4.5).

Table 2. Reliability statistics (n = 386)

Scale	Items	Cronbach’s α

Media content & format quality (MCC)	6	.812
Perceived media influence (MIN)	5	.883
Media-use attitude and satisfaction (MSA)	7	.923
Overall instrument	18	.948

4.3 Regression Analysis

Three regressions established the bivariate architecture of the model (Table 3). Content quality predicted perceived influence, $\beta = .741$, $R^2 = .549$, $F(1, 384) = 466.50$, $p < .001$, supporting H1. Content quality also predicted media-use attitude when entered alone, $\beta = .737$, $R^2 = .542$, $F(1, 384) = 455.26$, $p < .001$, and perceived influence was the strongest single predictor of attitude, $\beta = .804$, $R^2 = .647$, $F(1, 384) = 703.21$, $p < .001$, consistent with H2 and H3.

Table 3. Simple regression results ($n = 386$). *** $p < .001$.

Model	Path	B	SE	β	t	R^2	F
1	MCC $\rightarrow$ MIN	.926	.043	.741	21.60***	.549	466.50
2	MCC $\rightarrow$ MSA	.907	.043	.737	21.34***	.542	455.26
3	MIN $\rightarrow$ MSA	.793	.030	.804	26.52***	.647	703.21

4.4 Mediation Analysis

The mediation model was estimated with PROCESS Model 4 ($X = \text{MCC}$, $M = \text{MIN}$, $Y = \text{MSA}$; 5,000 bootstrap resamples). With both predictors entered, the model explained 69.1% of the variance in media-use attitude, $F(2, 383) = 427.77$, $p < .001$. Perceived influence remained the dominant predictor ($B = .565$, $SE = .042$, $\beta = .573$, $t = 13.55$, $p < .001$), supporting H2, while the direct effect of content quality stayed significant ($B = .384$, $SE = .052$, $\beta = .312$, $t =$

7.38, $p < .001$), supporting H3. The indirect effect of content quality on attitude through perceived influence was $B = .523$ ($\text{BootSE} = .069$, 95% CI [.388, .655]); in completely standardized form, .425 ($\text{BootSE} = .056$, 95% CI [.316, .533]). As the bootstrap interval excludes zero and the direct effect remains significant with the same sign, the pattern constitutes complementary partial mediation [12]: roughly 58% of the standardized total effect (.737) travels through perceived influence. H4 is supported. Figure 2 summarises the estimates.

Table 4. Mediation results, PROCESS Model 4 with 5,000 percentile bootstrap resamples ($n = 386$).

Effect	B	BootSE / SE	95% CI	Standardised
Total effect MCC $\rightarrow$ MSA	.907	.043	[.823, .990]	.737
Direct effect MCC $\rightarrow$ MSA (c')	.384	.052	[.282, .487]	.312
Indirect effect MCC $\rightarrow$ MIN $\rightarrow$ MSA	.523	.069	[.388, .655]	.425 [.316, .533]

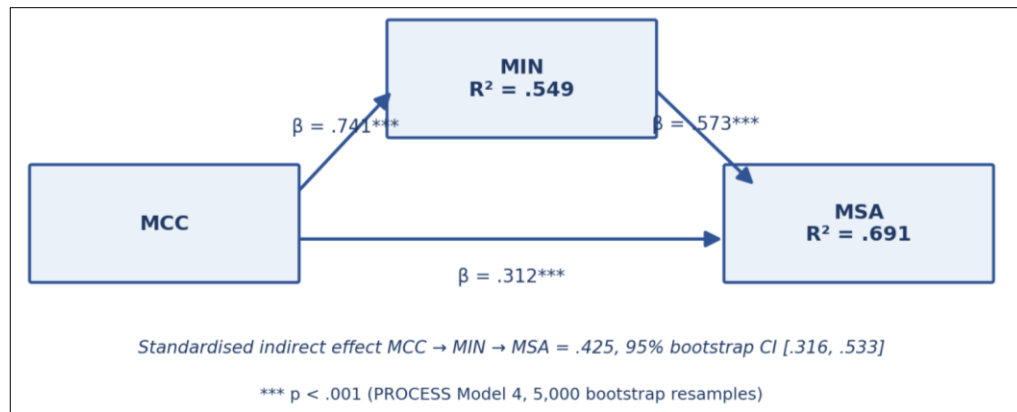


Figure 2. Structural results (standardized coefficients; PROCESS Model 4)

4.5 Structural Equation Model (PLS-SEM)

The model was re-estimated as a PLS-SEM in SmartPLS 4 (path-weighting scheme, Mode A; 5,000 percentile bootstrap resamples). The weak content-quality item identified in the reliability analysis (attractiveness of images) loaded at .248 and was removed, leaving five MCC indicators; all retained loadings exceeded .76 and were significant ($t \geq 25.66$). Construct reliability and convergent validity were satisfactory (Table 5): Cronbach's α ranged from .845 to .923, composite reliability (ρ_c) from .893 to .939, and AVE from .624 to .687. Discriminant validity was supported on both criteria: each construct's $\sqrt{\text{AVE}}$ (.790–.829) exceeded its correlations with the other constructs (.766–.808) [13], and all HTMT ratios remained below the .90 threshold [14,15] (MCC–MIN =

.879; MCC–MSA = .861; MIN–MSA = .890). Inner-model collinearity was unproblematic ($\text{VIF} = 2.42$), and the model achieved an SRMR of .069, below the .08 guideline. The structural estimates (Table 6) replicate the regression pattern: content quality strongly predicted perceived influence ($\beta = .766$, $t = 28.10$), perceived influence predicted media-use attitude ($\beta = .524$, $t = 8.56$), and the direct quality–attitude path remained significant ($\beta = .370$, $t = 6.22$), with $R^2 = .586$ (MIN) and .709 (MSA) and effect sizes f^2 of 1.416, .391, and .195 respectively. The specific indirect effect $\text{MCC} \rightarrow \text{MIN} \rightarrow \text{MSA}$ was .402 ($t = 7.90$, 95% CI [.300, .498]); with a significant same-sign direct effect, the PLS-SEM confirms complementary partial mediation (52% of the total effect of .772 mediated), corroborating H1–H4 in full.

Table 5. LS-SEM measurement model (SmartPLS 4, $n = 386$). All loadings are significant at $p < .001$. Fornell–Larcker satisfied: $\sqrt{\text{AVE}}$ (.790/.826/.829) exceeds inter-construct correlations (.766–.808); HTMT all $< .90$.

Construct	Item	Loading	α	CR (ρ_c)	AVE
MCC	MCC2–MCC6 (MCC1 removed, loading .248)	.775–.824	.845	.893	.624
MIN	MIN1–MIN5	.795–.848	.883	.915	.682

MSA	MSA1-MSA7	.765-.870	.923	.939	.687

Table 6. PLS-SEM structural model (5,000 percentile bootstrap resamples). $R^2(\text{MIN}) = .586$; $R^2(\text{MSA}) = .709$; SRMR = .069; all $p < .001$.

Hypothesis	Path	β	t	95% CI	f^2	Decision
H1	MCC $\rightarrow$ MIN	.766	28.10	[.710, .818]	1.416	Supported
H2	MIN $\rightarrow$ MSA	.524	8.56	[.398, .635]	.391	Supported
H3	MCC $\rightarrow$ MSA	.370	6.22	[.256, .491]	.195	Supported
H4	MCC $\rightarrow$ MIN $\rightarrow$ MSA	.402	7.90	[.300, .498]	—	Supported (partial mediation)

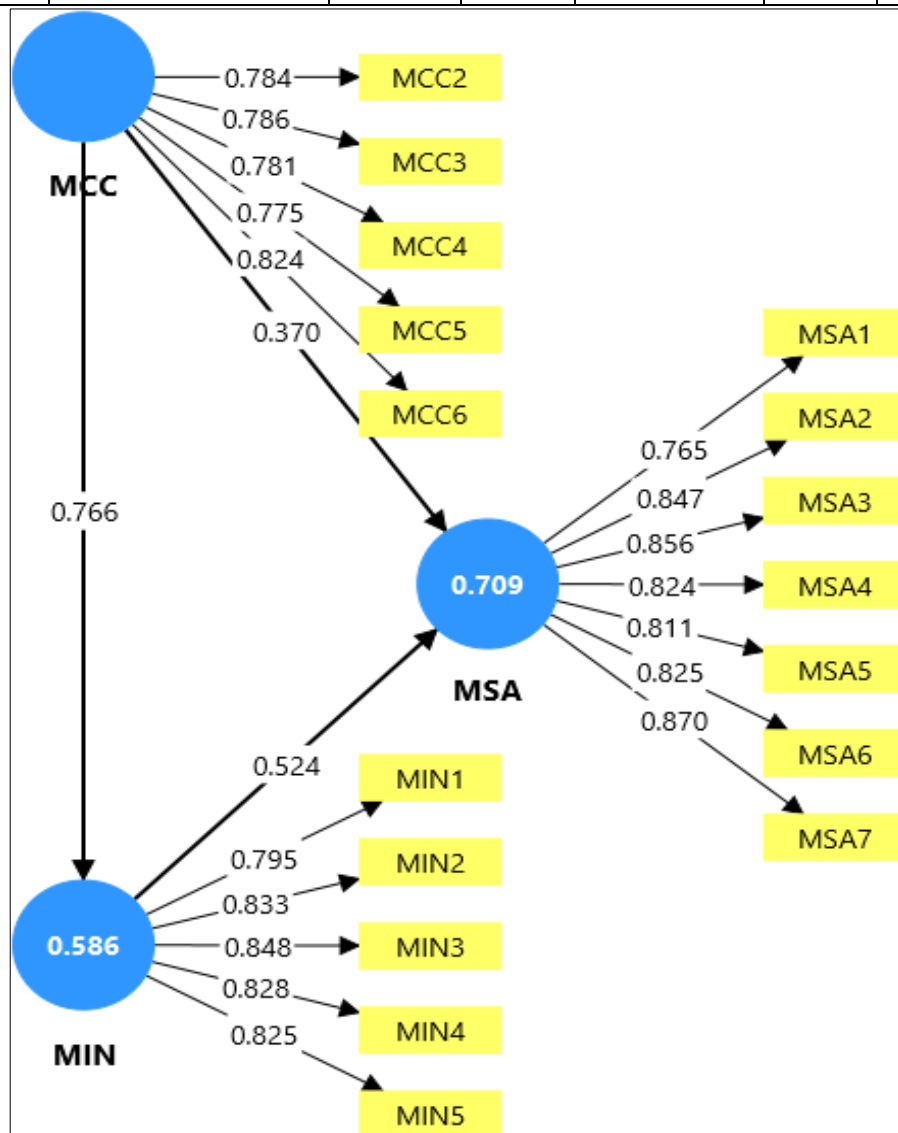


Figure 3. PLS-SEM estimation results (SmartPLS 4): outer loadings, standardized path coefficients, and R^2 values ($n = 386$).

5. DISCUSSION

5.1 Key Findings

Three results carry the argument. First, the quality of food-tourism content is a strong antecedent of perceived media influence: the MCC $\rightarrow$ MIN path ($\beta = .741$) indicates that tourists do not report being influenced by seeing much content; they report being influenced when the content they see is attractive, credible, concise, and accurate. Second, perceived influence converts into favorable media-use attitudes ($\beta = .573$, with quality controls), confirming that adoption experiences sediment into channel evaluations. Third, quality retains a direct attitudinal effect ($\beta = .312$) beyond what influence carries, so the mediation is partial rather than full—well-crafted content is appreciated even when a given decision is not visibly swayed by it. Together, the two predictors account for 69.1% of the variance in tourists' attitude towards food-tourism media.

5.2 Theoretical Implications

The findings extend the information adoption model [4] in two directions. The model's usual terminus is adoption or purchase intention [5]; here, the chain is carried one step further to the attitude towards the medium itself, and that step accounts for more than two-thirds of the attitude's variance. For gastronomy tourism specifically, the results qualify the contextual skepticism of Tham et al. [3]: social media influence may indeed be contingent, but in a

domain as visual and low-risk as food, content quality alone reproduces most of the influence mechanism. The strong contribution of the credibility and accuracy items within MCC also echoes the central-route emphasis of the elaboration likelihood model [6]—even in an aesthetically driven category, tourists appear to process culinary content as argument rather than merely as spectacle. The platform-based measurement of media-use satisfaction (Facebook, Instagram, Wongnai, TripAdvisor, Pantip, YouTube, Twitter/X) further suggests that tourists evaluate their media repertoire as a coherent whole: a single reliable scale ($\alpha = .923$) spanned seven platforms.

5.3 Practical Implications

For Bangkok's destination marketing organizations and tourism authorities, the managerial reading is direct: invest in the craft of content before it reaches. Campaigns that prioritize accurate information, credible sourcing, and high production values should outperform volume-led strategies, because quality is the variable that moves perceived influence and, through it, the attitudes that keep tourists consulting these channels. The behavioral profile sharpens the prescription: viewing photographs of attractions was respondents' most common online activity, and weekly or monthly food searches were the norm, so visually persuasive content placed in routine feeds—rather than burst campaigns—matches actual usage rhythms. For restaurateurs and street-food vendors,

the credibility items matter most: exaggerated imagery that the meal cannot honor risks damaging precisely the perceptions that drive adoption. For content creators, concision and factual reliability are not constraints on creativity but conditions of persuasive force, and consistency across the platform repertoire is likely to outperform platform-specific gimmickry.

6. LIMITATIONS AND FUTURE RESEARCH

Several limitations bound these conclusions. The design is cross-sectional and the data self-reported, so the paths represent theoretically ordered associations rather than demonstrated causation; the dominant first component in the method-variance check (54.2%) means common method variance may inflate the absolute size of the coefficients, even if it is unlikely to manufacture the pattern. One content-quality item (image attractiveness) showed weak discrimination and was removed from the PLS-SEM measurement model; the scale should be revisited in future refinements.

8. ACKNOWLEDGMENTS

The author gratefully acknowledges Rajamangala University of Technology Krungthep for the institutional support that enabled this study. Sincere thanks are extended to the expert panel who evaluated the questionnaire's content validity, and to all respondents who generously gave their time during data collection in Bangkok. Finally, the author sincerely thanks the staff

The sample, while adequately powered, was convenience-sampled in a single city, and five spending responses were missing. Experimental manipulation of content quality, longitudinal panels linking media attitudes to actual visitation, platform-specific comparisons, and contrasts between Thai and international tourists are natural next steps.

7. CONCLUSION

Food tourism is increasingly decided on screens, and this study shows that what happens on those screens is governed less by what tourists see than by how good it is. In a model explaining over two-thirds of the variance in tourists' attitudes towards food-tourism media, content quality emerged as the dominant upstream force, working chiefly through the experienced influence of media on real decisions. For a city whose kitchens are already world-famous, the message to Bangkok's marketers is encouragingly tractable: the next tourist meal is won with credible, beautiful, and accurate content. and students of the Department of Tourism, Faculty of Liberal Arts, for their kind assistance. This research received no external funding.

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Extreme Service, Customer Satisfaction, and Loyalty Intention in Omni-Channel Retail: Evidence from China

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ABSTRACT

Omni-channel retailing has reorganised the competitive logic of the global retail sector, shifting the locus of differentiation from price and assortment towards the quality and emotional resonance of the service experience. Within this shift, the notion of extreme service — a strategy of consistently exceeding customer expectations and forging affective bonds — has attracted growing attention, yet its mechanism in integrated retail settings, particularly in China, remains thinly evidenced. This study examines how four dimensions of extreme service (digital personalisation, fulfilment speed, experiential innovation, and channel consistency) shape customer satisfaction, and how satisfaction relates to loyalty intention. Drawing on the service-profit chain and service-dominant logic, a structural model was specified linking the four service dimensions to customer satisfaction and satisfaction to loyalty intention. Survey data were collected from 400 omni-channel customers of Pangdonglai Trading Group, a Chinese retailer known for employee empowerment and human-centred service, and analysed using structural equation modelling. Digital personalisation ($\beta = 0.32$) and fulfilment speed ($\beta = 0.34$) exerted the strongest effects on satisfaction, followed by experiential innovation ($\beta = 0.28$), while channel consistency showed no significant independent effect; satisfaction in turn strongly predicted loyalty intention ($\beta = 0.49$). The findings extend the service-profit chain to digitally integrated retail and offer retailers a prioritised agenda for service investment.

Keywords: extreme service; omni-channel retailing; customer satisfaction; loyalty intention; structural equation modelling; China

1. Introduction

The global retail industry is in the middle of a structural reordering. Statista [1] projects that the worldwide retail market will surpass US\$20.8 trillion by 2029, and McKinsey [2] estimates that e-commerce accounted for roughly 96% of net retail growth between 2019 and 2024. As the boundary between physical and digital channels dissolves, retailers have moved from operating parallel sales channels to managing a single integrated system in which membership, inventory, ordering, and fulfilment are orchestrated as one. Customers now expect to move between an app, a mini-programme, a social-commerce feed, and a physical store without friction and without losing the thread of a personalised relationship [3].

The contribution of this paper is threefold and is signalled here so that the argument that follows can be read against it. Theoretically, it joins the literature on extreme service to the literature on omni-channel capability, two streams that have developed in parallel, and embeds them in the service-profit chain. Methodologically, it constructs and validates a four-dimensional measure of extreme service fitted to digitally integrated retail and tests it within a structural model that links the service dimensions to customer satisfaction and satisfaction to loyalty intention. Practically, it converts a diffuse managerial aspiration — to delight the customer — into a prioritised and evidence-based agenda for where service investment yields the greatest return.

This integration has changed what customers reward. When assortment and price converge across competitors, the experience of being served — its speed, its relevance, its consistency, and its emotional texture — becomes the decisive margin. It is against this backdrop that the idea of *extreme service* has gained traction. Rather than meeting a service standard, extreme service is organised around exceeding expectations to the point of emotional surprise, converting transactions into relationships and relationships into advocacy [4, 5]. In an omni-channel environment, the construct acquires a distinctly digital character: personalisation is data-driven, fulfilment is engineered through store-as-warehouse and click-and-collect models, and consistency must hold across a proliferating set of touchpoints.

China offers an especially informative setting. Its retail ecosystem combines mature mobile payment, dense social commerce, and rapid last-mile logistics with consumers who interact with brands at high frequency and judge them on responsiveness. Within this market, Pangdonglai Trading Group has become a reference case for human-centred retailing, building its reputation on employee empowerment and a service ethos that customers describe in affective terms. The firm therefore provides a setting in which extreme service is not an abstraction but an operating principle, allowing its effects on customer outcomes to be observed where the practice is most fully developed.

The strategic stakes are not trivial. Evidence from service-management research suggests that a five-percentage-point lift in customer retention can raise profit by between a quarter and a near-doubling, depending on the sector, and surveys repeatedly find that a large majority of consumers will pay a premium for service they regard as superior [6]. In a market where acquisition costs are rising and switching costs are falling, the economics of retention place service quality at the centre of competitive strategy rather than at its periphery. Yet retention is a downstream outcome; what a manager can act on is the upstream service design and the capabilities that deliver it. Understanding which dimensions of service move satisfaction, and under what organisational conditions, is therefore not merely an academic question but a question of where scarce investment should go.

Despite the managerial enthusiasm, the empirical record lags the rhetoric. Most prior work treats omni-channel integration and service quality separately, or examines the omni-channel–satisfaction link without specifying the service strategy that drives it [7]. Extreme service is rarely modelled as a multidimensional antecedent of satisfaction, and the role of satisfaction in linking extreme service to loyalty is seldom tested under omni-channel conditions [8]. This study addresses those gaps by asking two questions. First, to what extent do the dimensions of extreme service influence customer satisfaction in an omni-channel

setting? Second, how does customer satisfaction relate to loyalty intention? In answering them, the paper integrates the service-profit chain with the omni-channel paradigm, validates a four-dimensional measure of extreme service, and tests a structural model on data from 400 Chinese omni-channel customers.

2. Theoretical Background and Hypotheses

2.1 Omni-channel retailing and the service-profit chain

Omni-channel retailing is a customer-centred strategy that integrates touchpoints, processes, and data so that goods, information, and service flow seamlessly across channels [3, 9]. It rests on several theoretical pillars. Customer-experience theory holds that a coherent, low-friction journey raises cognitive, affective, and behavioural responses; service-dominant logic recasts each touchpoint as a site of value co-creation [10]; and the resource-based view treats unified data platforms and integrated inventory as capabilities that underpin durable advantage. The service-profit chain links these strands into a causal sequence: internal capability enables service quality, service quality produces satisfaction, and satisfaction yields loyalty and, ultimately, financial performance [11]. This study adopts that chain as its organising logic and positions extreme service as the quality construct that initiates it.

Positioning extreme service within this chain also clarifies what it is not. It is not the

same as conventional service quality as measured by instruments such as SERVQUAL, which benchmark performance against expectation and treat meeting expectation as success [12]. Extreme service sets a higher bar: the relevant comparison is not whether expectations were met but whether they were exceeded by enough to generate affect. Nor is it reducible to omni-channel integration, which describes the structural condition of the channels rather than the quality of what flows through them. A retailer can be fully integrated and yet unremarkable. Extreme service is therefore best understood as the experiential content that integration makes deliverable, and the present model treats the two as complements: integration is the platform, extreme service is the performance.

2.2 Extreme service and its dimensions

Extreme service describes a deliberate strategy of surpassing expectations through highly personalised care and emotional connection, such that customers feel not merely served but moved [4, 5]. Translated into the omni-channel context, the construct is best understood as multidimensional. Digital personalisation captures the use of analytics and artificial intelligence to tailor offers and communication across channels [7, 13]. Fulfilment speed concerns the timeliness, accuracy, and reliability of delivery, pickup, and returns [14, 15]. Experiential innovation refers to the design of novel, emotionally engaging experiences that exceed functional expectation [5]. Channel

consistency denotes the uniformity of brand message, pricing, and service quality across online and offline touchpoints [16, 17]. Each dimension addresses a distinct facet of the customer journey, and each has been independently associated with satisfaction in adjacent literatures.

Personalisation works because relevance reduces search effort and signals recognition, which carries affective weight [18]. Fulfilment speed matters because, in high-frequency digital retail, the moment of delivery is where promises are kept or broken; last-mile quality has become a primary driver of satisfaction and repeat purchase [19, 20]. Experiential innovation contributes by sustaining novelty and emotional engagement, deepening attachment beyond the functional core. Consistency operates more defensively: incoherence across channels erodes the trust that integration is meant to build [21]. Taken together, these arguments motivate the first hypothesis family.

H1. The dimensions of extreme service positively influence customer satisfaction — specifically digital personalisation (H1a), fulfilment speed (H1b), experiential innovation (H1c), and channel consistency (H1d).

2.3 Satisfaction and loyalty

Customer satisfaction is the affective evaluation that connects service quality to subsequent behaviour [22]. Within the service-profit chain it is the pivotal outcome of service quality and the proximal antecedent of loyalty: quality is experienced,

satisfaction is formed, and loyalty follows. Loyalty intention — the disposition to repurchase and recommend — is the behavioural consequence of satisfaction [22, 23], and a substantial body of omni-channel research confirms the link under conditions of channel integration [24, 25]. This reasoning yields the study’s second hypothesis. **H2.** Customer satisfaction positively influences loyalty intention.

2.4 Conceptual framework

Figure 1 integrates the hypotheses into a single model. The four extreme-service dimensions act as exogenous antecedents of customer satisfaction (H1), and satisfaction in turn shapes loyalty intention (H2), giving the service-profit chain a compact, testable form in the omni-channel setting.

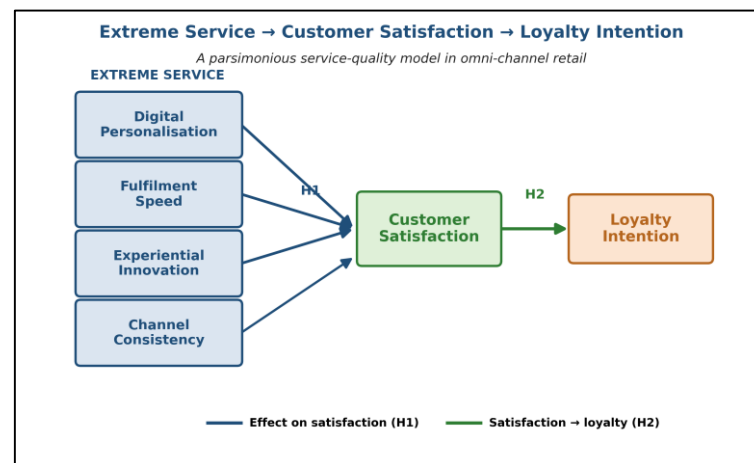


Figure 1. Conceptual framework linking the extreme-service dimensions to customer satisfaction and loyalty intention.

2.5 Synthesis of prior empirical evidence

The hypotheses do not arise in a vacuum; a growing body of omni-channel research in Asia and elsewhere has examined the constituent links, though rarely within a single model. Table 1 synthesises representative studies, organised by the dimension or relationship each addresses. Two patterns emerge. First, personalisation and fulfilment recur as the most consistently significant antecedents of satisfaction and loyalty, across markets from Indonesia to China and

Taiwan. Second, channel consistency is repeatedly tied to trust and loyalty, but its effect is often mediated by integration quality rather than direct, which anticipates this study’s finding that its independent path weakens once other dimensions are present. Reviewing this evidence together exposes its principal limitation: the relationships have been tested piecemeal, leaving the joint structure that managers actually confront largely unexamined.

Table 1. Synthesis of representative empirical studies on omni-channel service and customer outcomes.

Study (year)	Context	Focal variables	Method	Main finding
Susanti, Widyastuti, & Nugroho (2023)	Omni-channel, Indonesia	Personalisation, fulfilment, satisfaction	Survey (n=350), SEM	Personalisation and delivery speed significantly raise satisfaction and loyalty.
Xu, Chen, & Chen (2023)	Retail, China	Digital transformation, experience, loyalty	Survey (n=412), SEM	Analytics integration strengthens personalised experience and loyalty via satisfaction.
Zhang, Yang, & Li (2022)	Omni-channel logistics, China	Fulfilment reliability, satisfaction, loyalty	Quantitative modelling	Fulfilment accuracy and speed directly influence satisfaction and repurchase.
Tristanto, Nugraha, & Lestari (2023)	Retail experience, SE Asia	Experiential innovation, engagement, loyalty	Survey (n=280), CFA & SEM	Experiential innovation mediates loyalty through engagement and attachment.
Chen & Su (2023)	Omni-channel, Taiwan	Channel consistency, trust, loyalty	Online survey (n=400)	Consistency strengthens trust and loyalty; integration quality mediates.
Zhou, Lu, & Wang (2021)	Multi-channel, China	Integration quality, organisational capability	Survey (n=320), SEM	Integration raises loyalty; organisational agility moderates the relationship.

3. Methodology

3.1 Research design

The study adopts a quantitative, single-case survey design, using Pangdonglai Trading Group as the empirical setting. A quantitative approach was chosen over a mixed design for three reasons. Standardised instruments yield comparable data across a large sample, strengthening the reliability of estimates; structural equation modelling (SEM) tests

multidimensional causal relationships among latent variables more rigorously than regression alone; and SEM estimates the measurement and structural models jointly, improving both validity and interpretability. The single-case focus trades breadth for depth: by studying a firm where extreme service is most fully realised, the design observes the construct under near-ideal conditions, with the understandable cost

that generalisation requires replication elsewhere.

3.2 Population, sampling, and sample size

The target population comprised Pangdonglai customers who had purchased through both online and offline channels within the preceding six months, a screening criterion that anchors evaluations in genuine omni-channel experience and limits recall bias [3]. Because the omni-channel customer base is large and fluid, non-probability sampling was used, combining convenience and quota sampling to balance representation across gender, age, and shopping frequency. Questionnaires were distributed both online, through channels closely associated with the retailer such as WeChat, and offline, through in-store QR codes and paper forms, so that both digitally

inclined and store-oriented customers were reached. Following the guidance that SEM requires roughly 10 to 15 cases per observed variable [28], a target of 400 valid responses was set; this sample supports stable estimation and adequate statistical power.

3.3 Measures

All latent constructs were measured with multi-item, five-point Likert scales adapted from validated sources and refined for the omni-channel context. The four extreme-service dimensions, customer satisfaction, and loyalty intention were each measured with four items. Demographic and behavioural items (age, gender, channel use, shopping frequency, membership) were retained as controls. Table 1 summarises the constructs, their operational definitions, and source scales.

Table 2. Construct definitions, item counts, and source scales.

Construct	Operational definition	Items	Key sources
Digital personalisation	Use of analytics and AI to tailor offers and communication across channels	4	[7, 13]
Fulfilment speed	Perceived timeliness, accuracy, and reliability of delivery, pickup, and returns	4	[14, 15]
Experiential innovation	Design of novel, emotionally engaging experiences beyond function	4	[5]
Channel consistency	Uniformity of message, pricing, and service across touchpoints	4	[16, 17]
Customer satisfaction	Overall affective evaluation of the shopping experience	4	[22]
Loyalty intention	Intention to repurchase and recommend the retailer	4	[23]

3.4 Validation and data collection

Content validity was established through expert review: three subject-matter specialists rated each item, and the item-objective congruence (IOC) index was computed. All retained items achieved an IOC of at least 0.67, the conventional threshold, with most reaching 1.00, indicating strong agreement on relevance. A pilot test preceded full deployment to confirm clarity and internal consistency, after which minor wording revisions were made. Informed consent was obtained from every respondent, participation was voluntary and anonymous, and the protocol followed institutional ethics requirements.

Two design choices warrant defence against the alternatives a reviewer might prefer. A reviewer might favour a probability sample; in a population as large, anonymous, and continuously changing as a major retailer's omni-channel customer base, however, no sampling frame exists from which to draw one, and the quota controls used here secure representativeness on the dimensions that matter for the analysis without the false precision of a frame that cannot be constructed. A reviewer might also prefer a mixed-methods design; yet the research questions concern the magnitude and structure of relationships among well-specified constructs, which quantitative modelling answers directly, whereas qualitative depth, valuable for theory

generation, is not what a confirmatory test of an a priori model requires.

3.5 Analytical strategy

Analysis proceeded in two stages following the conventional SEM workflow. The measurement model was first assessed for reliability and convergent and discriminant validity, after which the structural model was estimated to test the hypothesised paths. Model fit was judged against established thresholds for the normed chi-square ($\chi^2/df < 3.0$), RMSEA (< 0.08), CFI and TLI (> 0.90), and SRMR (< 0.08).

4. Results and Discussion

4.1 Sample profile and descriptive statistics

All 400 distributed questionnaires were returned usable after screening for completeness and the six-month omni-channel eligibility criterion, giving a clean analytic sample. The profile, summarised in Table 5, shows a sample skewed slightly female (mean gender code 1.36) and concentrated in the younger-to-middle age bands (mean age code 2.05 on a four-point scale). Channel use was mixed, with a near-even split between predominantly online and predominantly offline shoppers (mean 1.39), and most respondents shopped at least monthly (mean frequency code 1.74). Roughly two-thirds belonged to the retailer's loyalty programme. This balance across channels and segments is what the quota

design sought, and it supports comparison across groups in the structural analysis.

Table 3. Respondent profile (N = 400).

Profile variable	Coding	Mean	SD
Age band	1–4 (young → older)	2.05	1.12
Gender	1 = female, 2 = male	1.36	0.48
Primary channel	1 = online, 2 = offline	1.39	0.49
Shopping frequency / month	1–3 (low → high)	1.74	0.82
Loyalty-programme member	1 = yes, 2 = no	1.34	0.47

Item means for the extreme-service constructs clustered between 2.3 and 3.1 on the five-point scale, indicating moderate perceived performance with clear room for improvement. Fulfilment items recorded the lowest values — on-time delivery averaged 2.34 and order accuracy 2.59 — while awareness of newly launched services reached only 2.46, suggesting that experiential novelty was the least salient dimension in customers' minds. Personalisation items were somewhat higher (2.80–3.02), and loyalty-intention items recorded the highest means overall, with the intention to continue shopping reaching 3.13. The pattern is diagnostically useful: the dimensions that customers rated lowest are

precisely those the structural model identifies as the strongest levers of satisfaction, implying unrealised return on service improvement.

4.2 Measurement model

The measurement model demonstrated satisfactory reliability and validity. Composite reliability and Cronbach's alpha for every construct exceeded the 0.70 benchmark, average variance extracted surpassed 0.50, confirming convergent validity, and the square root of each AVE exceeded the inter-construct correlations, supporting discriminant validity. The model achieved a good overall fit, as shown in Table 4, with all indices meeting or bettering their thresholds.

Table 4. Measurement model fit indices.

Fit index	Threshold	Observed value	Interpretation
χ^2/df	< 3.0	2.11	Acceptable
RMSEA	< 0.08	0.054	Good
CFI	> 0.90	0.946	Very good
TLI	> 0.90	0.932	Very good
SRMR	< 0.08	0.043	Excellent

4.3 Structural model and hypothesis tests

The structural estimates, reported in Table 5, support the core of the model. Among the extreme-service dimensions, fulfilment speed ($\beta = 0.337$, $p < 0.001$) and digital personalisation ($\beta = 0.321$, $p < 0.001$) were the strongest predictors of satisfaction, with experiential innovation also significant

($\beta = 0.275$, $p = 0.004$). Channel consistency did not yield a significant independent path to satisfaction once the other dimensions were accounted for, so H1d was not supported while H1a–H1c were. Satisfaction in turn strongly predicted loyalty intention ($\beta = 0.492$, $p < 0.001$), supporting H2.

Table 5. Structural model results (standardised path coefficients).

Path	β	S.E.	C.R.	p	Result
Digital personalisation $\rightarrow$ Satisfaction	0.321	0.073	4.40	< 0.001	Supported (H1a)
Fulfilment speed $\rightarrow$ Satisfaction	0.337	0.078	4.32	< 0.001	Supported (H1b)
Experiential innovation $\rightarrow$ Satisfaction	0.275	0.095	2.90	0.004	Supported (H1c)
Satisfaction $\rightarrow$ Loyalty intention	0.492	0.069	7.13	< 0.001	Supported (H2)

4.4 The validated model

Figure 2 presents the empirically validated model, annotated with the standardised path coefficients reported above. It is the proposed framework of Figure 1 after estimation: the relationships the data supported are drawn as solid paths carrying

their coefficients, while the relationship that did not survive estimation — the independent path from channel consistency to satisfaction — is shown as a dashed, greyed link. The contrast between the two figures is itself informative, since it shows which a priori expectations held and which were revised by the evidence.

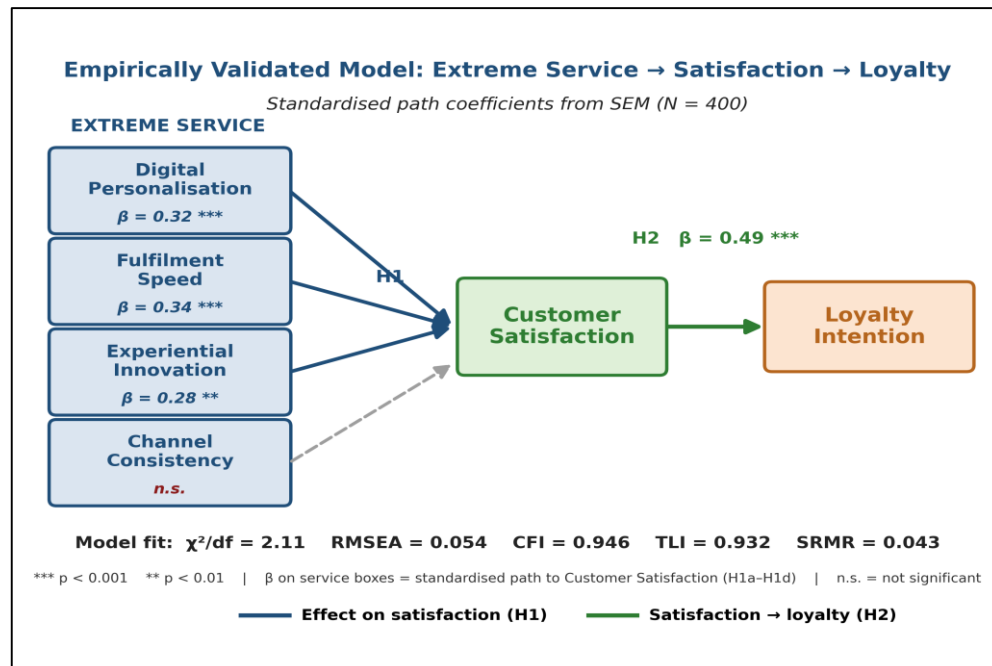


Figure 2. Empirically validated structural model with standardised path coefficients (N = 400). Solid paths are significant; the dashed grey path was non-significant. * $p < 0.001$; $p < 0.01$.

The estimated model confirms the core of the proposed framework while sharpening it. Of the four extreme-service dimensions, fulfilment speed ($\beta = 0.34$, $p < 0.001$) and digital personalisation ($\beta = 0.32$, $p < 0.001$) emerged as the dominant drivers of customer satisfaction, with experiential innovation contributing more modestly ($\beta = 0.28$, $p < 0.01$); channel consistency, by contrast, carried no significant independent path once the other dimensions were accounted for. Customer satisfaction then exerted a strong influence on loyalty intention ($\beta = 0.49$, $p < 0.001$), confirming its position as the pivotal link between service quality and customer loyalty. The model achieved a good overall fit ($\chi^2/df = 2.11$; RMSEA = 0.054; CFI = 0.946; TLI = 0.932; SRMR

0.043), lending confidence to these estimates.

4.5 Discussion of Findings

The results give empirical substance to a model that practitioners have largely taken on faith. The headline finding is that fulfilment speed and digital personalisation are the dominant drivers of satisfaction in omni-channel retail, ahead of experiential innovation and channel consistency. This ordering is theoretically coherent. In a high-frequency digital market, relevance and reliability are the attributes a customer encounters on every visit, whereas novelty is episodic and consistency is noticed mainly in the breach. The primacy of personalisation echoes Lemon and Verhoef's [18] argument that relevance delivered through digital touchpoints is central to experience quality, and the strength of fulfilment speed aligns

with recent evidence that last-mile performance now anchors satisfaction in integrated retail [19, 20].

It is worth dwelling on the dimension that did not behave as theorised. Channel consistency, despite its prominence in the omni-channel literature, did not retain a significant independent path to satisfaction once personalisation, fulfilment, and innovation were in the model. Two readings are plausible and not mutually exclusive. The first is empirical: at a retailer as integrated as the studied firm, consistency may be a hygiene factor that customers notice only when it fails, so that variance is too compressed to register a distinct effect. The second is measurement-related: consistency may be partly absorbed by the other dimensions, since a personalised, reliably fulfilled experience is itself experienced as coherent. Prior work pointing to mediation of consistency through trust and integration quality [26, 29] lends weight to the first reading. Either way, the result cautions against assuming that every theoretically attractive dimension will earn its place in an estimated model.

4.6 Theoretical Implications

The study makes two theoretical contributions. It integrates two previously separate streams — extreme service and omni-channel capability — into a single validated framework, and it operationalises extreme service as a four-dimensional construct suited to digitally integrated retail.

In showing that relevance and reliability, rather than novelty or surface coherence, are the dimensions that most strongly move satisfaction, it gives the service-profit chain a digitally specified form and clarifies which facets of service quality most effectively initiate the chain in omni-channel retail.

4.7 Managerial Implications

For retail managers, the findings translate into a prioritised agenda. Because personalisation and fulfilment speed carry the heaviest weight, investment should flow first to customer-data platforms, intelligent recommendation engines, and the warehousing and last-mile capabilities that make delivery promises credible; store-as-warehouse and instant-pickup models are concrete levers here. Consistency across price, brand, and service should be managed as a cross-functional discipline, since incoherence quietly erodes the trust that integration is meant to create.

A second managerial lesson concerns sequencing. The descriptive data show that the dimensions customers rated lowest — fulfilment reliability and awareness of new services — are among those the model identifies as the strongest drivers of satisfaction. This is the signature of unrealised return: the firm is weakest precisely where improvement would pay most. Managers can read the two analyses together as a diagnostic, mapping perceived performance against estimated leverage to locate the quadrant where low performance meets high

impact, and directing the next increment of investment there rather than towards dimensions that are already strong or that move satisfaction little. Treating service investment as a portfolio governed by leverage, rather than as an undifferentiated commitment to excellence, is the practical discipline the findings recommend.

4.8 Limitations and Future Research

Several limitations qualify the findings and chart the path forward. The single-case, single-market design secures depth at the expense of breadth; replication across multiple Chinese retailers and other national contexts is needed before the model can be generalised. Non-probability sampling and self-reported, cross-sectional data introduce the usual risks of selection and common-method bias and preclude strong causal claims; longitudinal or multi-source designs would strengthen inference. Channel consistency, though theoretically central, did not emerge as an independent driver in this sample, which may reflect the studied firm's already-high integration or measurement overlap with the other dimensions — a question worth disentangling in settings with more channel variance. Future work might also incorporate objective behavioural and financial data alongside perceptions, and examine boundary conditions such as product category and customer tenure.

4.9 Contribution to Knowledge

Read as a whole, the validated model shows that extreme service shapes customer satisfaction in omni-channel retail not through novelty or surface coherence but through the everyday fundamentals of relevance and reliability, and that satisfaction, once formed, translates into loyalty intention. From this, two contributions to knowledge follow. First, the study extends the service-profit chain to the digitally integrated retail context by validating the sequence from extreme service through satisfaction to loyalty intention with data from a leading human-centred retailer. Second, it offers a validated four-dimensional operationalisation of extreme service for omni-channel settings and, in finding that channel consistency does not stand as an independent driver once relevance and reliability are present, refines rather than merely confirms the prior literature. The practical reading is one of prioritisation: retailers should invest first in personalisation and fulfilment, because these move satisfaction most and, through it, loyalty.

4.10 Conclusion

This study set out to explain how extreme service shapes customer outcomes in China's omni-channel retail environment. Using survey data from 400 Pangdonglai customers and structural equation modelling, it shows that digital personalisation and fulfilment speed are the principal engines of satisfaction, and that satisfaction carries these effects through to

loyalty intention. The contribution is to give the service-profit chain a digitally specified, empirically tested form in the omni-channel setting, and to offer retailers a clear order of priorities: serve with relevance and reliability, and satisfaction — and the loyalty that follows — will follow in turn.

5. ACKNOWLEDGMENTS

The authors are sincerely grateful to all the customers who generously gave their time to complete the survey; their participation provided the empirical foundation on which this study rests. We also wish to acknowledge the support of the International College, Rajamangala University of Technology Krungthep, which provided the academic environment and facilities that made this research possible. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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Influence of YouTube Video Reviews on Purchase Intentions of Thai Consumers

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Abstract

According to the Stimulus-Organism-Response (S-O-R) model, this paper examines the impact of YouTube product review videos on the intention to purchase for Thai consumers. The analysis focuses on audience engagement indicators, including views, likes, comments, and replies, to explore how these observable interactions influence consumers' evaluations of review credibility and informational value. The analysis draws upon survey responses collected from 400 participants in Bangkok, Thailand. For language uniformity, first write the survey in English, then translate it into Thai, and finally back-translate before distribution. Partial Least Squares Structural Equation Modelling (PLS-SEM) is used to test the proposed theoretical system. Based on the hypothesis testing results, this study found that Number of Views, Likes, Comments, and Replies have positive and significance association with perceived credibility of the information in the video, perceived usefulness of information in the videos, attitude toward purchase and purchase intention of Thai consumers.

Keywords: YouTube product reviews; purchase intention; perceived credibility; perceived usefulness; engagement metrics

1. INTRODUCTION

The rapid development of digital technologies and widespread internet access have significantly transformed the way consumers obtain product-related information before making purchasing decisions. In Thailand, YouTube has evolved into one of the primary online platforms where consumers search for product reviews, demonstrations, and personal experiences shared by other users. Compared with conventional advertising, these review videos provide richer information and practical experiences that enable consumers to evaluate products more carefully while reducing uncertainty during the purchasing process.

Besides the review content itself, YouTube also presents visible engagement indicators, including the number of views, likes, comments, and replies. Rather than serving only as platform statistics, these indicators often function as social cues that influence how consumers interpret the credibility and usefulness of review information. Videos receiving higher levels of interaction are generally perceived as being more reliable, informative, and widely accepted by other viewers. Such perceptions may subsequently influence consumers' attitudes toward products and their willingness to make a purchase. This effect is particularly relevant in Thailand, where consumers frequently consider the opinions and experiences of others before making purchasing decisions.

Although electronic word-of-mouth (eWOM), influencer promotion and online feedback have been studied to some extent in previous research, relatively few researchers have specifically explored the influence of YouTube engagement indicators on purchase intention through consumers' psychological evaluations. Existing evidence also provides limited empirical findings from Thailand despite the country's high level of YouTube usage. Addressing this research gap offers a clearer understanding of how social engagement signals contribute to consumers' purchasing behaviour within the Thai market.

The present research applies the Stimulus–Organism–Response (S–O–R) framework to explain these relationships. Within this framework, engagement indicators act as external stimuli, whereas perceived credibility, perceived usefulness, and attitude toward purchase represent consumers' internal evaluations that ultimately shape purchase intention. To study the above associations, online questionnaires were distributed to the Thai people, and then PLS-SEM was employed to analyse the theoretical framework.

Finally, this paper hopes to add new content to the current knowledge base of digital advertising, online word-of-mouth and shopper behaviour by applying the utility of the S-O-R model to YouTube merchandise critique clips in Thailand. The above results will provide some practical references for advertising and media companies that want to use YouTube more efficiently for promotion.

2. RESEARCH OBJECTIVES

The present study was designed to achieve the following research objectives:

- To study the effect of YouTube interaction indicators, such as view counts, likes, comments and replies, on Thai consumers' perception of the reliability and usefulness of product evaluation videos.

- To study the connection between perceived trustworthiness, perceived practicality, buying tendency and purchase intention based on the background of YouTube commodity reviews.
- To investigate the effect of the level of YouTube interaction on the purchase intention of Thai consumers by means of the Stimulus-Organism-Response (S-O-R) model.

3. RESEARCH HYPOTHESIS

H1: A relatively large number of likes, comments, etc., on a YouTube post can make consumers think that it has been reviewed by others.

H2: High levels of YouTube engagement indicators (such as views, likes, comments and replies) can make people believe that the product review information is more useful.

H3: The level of trust in the source of YouTube product reviews affects people's perception of the helpfulness of that information.

H4: Consumers' perception of the credibility of YouTube product review information positively affects their intention to buy.

H5: The higher a consumer's credibility of the information about YouTube product reviews, the stronger their willingness to buy will be.

H6: Consumers' perceived usefulness of YouTube product review information positively influences their attitude toward purchasing.

H7: Consumers' perceived usefulness of YouTube product review information positively influences their purchase intention.

4. CONTRIBUTION

Although electronic word-of-mouth, online reviews, and influencer marketing have received considerable scholarly attention, limited research has specifically examined how YouTube engagement metrics—such as views, likes, comments, and replies—influence consumers'

purchase intentions through perceived credibility and perceived usefulness, particularly within the Thai context. Based on the above interaction indicators, this paper will extend the S-O-R model to offer a more comprehensive explanation of the psychological reasons why consumers buy after viewing YouTube merchandise review videos. Consequently, the study extends existing knowledge in digital marketing, social commerce, and consumer behavior by offering evidence from an emerging market where YouTube is used by consumers to search for and learn about goods. Based on the above results, some suggestions are put forward to enhance the efficiency of YouTube in digital marketing for enterprises, advertisers and media companies. Rather than focusing solely on producing promotional content, organizations should also encourage meaningful audience engagement and provide review information that is both credible and useful. Strengthening these

aspects can increase consumers' trust, improve their evaluations of review information, and ultimately enhance their willingness to purchase the promoted products.

5. CONCEPTUAL FRAMEWORK

The conceptual framework in this study presents the connections among the main research variables that have been proposed. The model identifies YouTube engagement metrics, represented by the number of views, likes, comments, and replies (NVLCR), as the external stimulus influencing consumers' psychological evaluations. Credibility and utility are expected to explain the effect of the above engagement factors on consumers' willingness to purchase, thus modifying their intention to buy. The new framework is as follows: Figure 1.

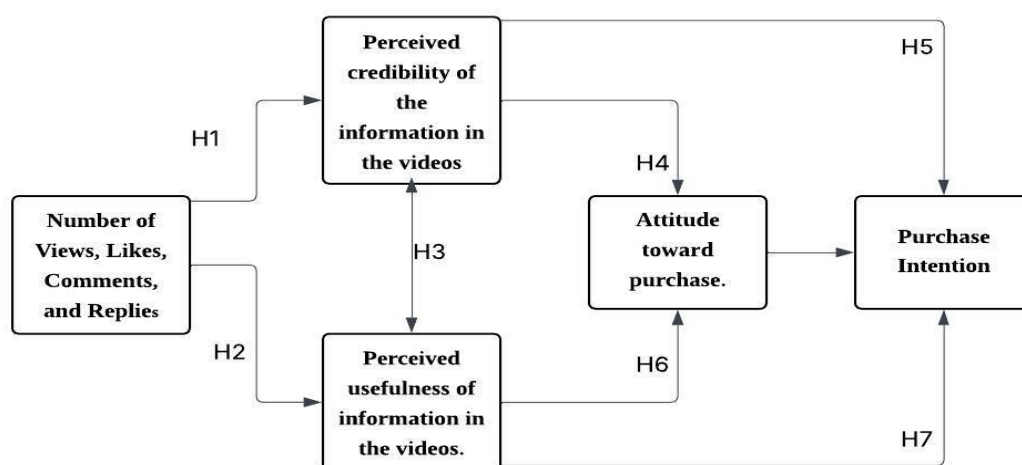


Figure 1. Conceptual framework of the study

6. THEORIES AND LITERATURE REVIEWS

The Stimulus-Organism-Response (S-O-R) model will be used to study why people are attracted to YouTube product review videos. According to this perspective, individuals first encounter environmental stimuli, which shape their internal evaluations before influencing subsequent

behavioural responses. In the present study, YouTube engagement indicators—including views, likes, comments, and replies—represent the external stimuli. Consumers' perceptions of credibility and usefulness reflect their internal psychological responses, while purchase intention represents the behavioural outcome.

YouTube has become one of the most influential platforms for obtaining product-related information. Unlike traditional advertising, review videos combine visual demonstrations with users' personal experiences and interactive discussions, allowing potential buyers to assess products from multiple perspectives before making purchasing decisions. Such information reduces uncertainty during product evaluation and helps consumers make more informed choices. Earlier research has consistently shown that consumers place greater trust in review content when it is perceived as credible, informative, and relevant to their purchasing needs.

Visible engagement indicators displayed on YouTube also provide valuable social information. Rather than being simple numerical statistics, views, likes, comments, and replies can be interpreted as signals reflecting public interest and social approval. Therefore, the review videos with higher levels of engagement are more likely to be perceived as trustworthy and useful. As consumers come to know their own lives better, they will probably start to like these products more and wish to purchase them.

According to the S-O-R model and previous research, the indicators of engagement are likely to affect the intention to purchase through altered consumers' psychological evaluations. In other words, it is expected that the impact of social interaction signals on attitudes towards purchase and subsequent purchase intention will be explained by perceived credibility and perceived usefulness. This framework provides a comprehensive explanation of the decision-making process associated with YouTube product review videos among Thai consumers.

7. RESEARCH METHODOLOGY

A design for a quantitative survey will be employed to investigate the relationship between YouTube product review videos and consumers' intention to purchase in this paper. The research focused on Thai consumers aged 18 years and above who had previously viewed YouTube product review videos before making purchasing decisions. Participants were recruited using a convenience sampling approach, and responses were collected through an online questionnaire created with Google Forms. A total of 483 valid questionnaires were collected for analysis, and thus met the lower bound of the sample size required by the statistical methods in this study.

To guarantee the quality and consistency of the survey tool, it was first prepared in English, then translated into Thai, and finally back-translated before being used in the distribution. The measurement instrument included five principal constructs: YouTube interaction indicators (views, likes, comments and replies), perceived reliability, perceived utility, buying sentiment and buying intention. Adapt the evaluation items from validated research and, at a five-point Likert scale, have respondents rate them from 1 (strongly disagree) to 5 (strongly agree).

Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed to analyze the proposed theoretical framework using WarpPLS. First of all, at this time, the reliability and validity of the measurement model have been confirmed prior to investigating the connections among the variables. The above structure model will be used to test the hypotheses proposed in this study and examine the relationship among all research factors.

8. RESULT

Measure the extent to which the measured system can be reliably used to verify the above hypotheses. All the constructs had good psychometric properties in this test. The composite

reliability (CR) values were 0.867 and 0.899, respectively; as both exceeded the required 0.70 threshold, the data met the condition for good internal consistency. The average variance extracted (AVE) values were between 0.621 and 0.689, and thus the convergent validity was deemed acceptable. In addition, all indicator loadings were above 0.70, providing further evidence of measurement reliability.

The next will be the Fornell-Larcker criterion for discriminant validity testing. The square root of the AVE for each variable was larger than its correlations with other variables, and thus met the condition for discriminant validity. In addition, the Variance Inflation Factor (VIF) values ranged from 1.061 to 1.087; therefore, there was no problem of multicollinearity in the proposed system.

A measured system was developed based on validation to conduct Partial Least Squares

Structural Equation Modeling (PLS-SEM) for path analysis. The statistical analysis provided support for all seven hypotheses. YouTube engagement metrics were positively associated with perceived credibility ($\beta = 0.238$, $p < .001$) and perceived

usefulness ($\beta = 0.168$, $p < .001$). Perceived credibility also showed significant positive relationships with perceived usefulness ($\beta = 0.215$, $p < .001$), attitude toward purchase ($\beta = 0.248$, $p < .001$), and purchase intention ($\beta = 0.201$, $p < .001$). Likewise, perceived usefulness demonstrated significant positive effects on both attitude toward purchase ($\beta = 0.201$, $p < .001$) and purchase intention ($\beta = 0.234$, $p < .001$).

The extent of the explanation achieved by the structure model met the requirements. The coefficients of determination (R^2) for perceived credibility, perceived usefulness, attitude towards purchase and purchase intention were 0.060, 0.090, 0.130 and 0.120, respectively. The complete structural model is presented in Figure 2, while the hypothesis testing results are summarised in Table 2.

Table 1. Correlations, Multicollinearity, and Divergent Validity Indicators

Construct	CR	VIF	NVLCR	PC	PU	ATP	PI
NVLCR	0.881	1.068	0.806	0.228	0.2	0.19	0.251
PC	0.899	1.087	0.228	0.83	0.254	0.291	0.215
PU	0.897	1.087	0.2	0.254	0.828	0.243	0.212
ATP	0.875	1.061	0.19	0.291	0.243	0.799	0.222
PI	0.867	1.061	0.251	0.215	0.212	0.222	0.788

Notes: The values on the diagonal are the square roots of the average variance extracted (AVE). NVLCR = Number of Views, Likes, Comments and Replies; PC = Perceived Credibility; PU = Perceived Usefulness; ATP = Attitude Towards Purchase; PI = Purchase Intention.

The PLS-SEM results shown in Figure 2 confirm support for all proposed hypotheses. Higher levels of YouTube engagement were positively associated with both perceived credibility ($\beta = 0.238$, $p < .001$)

and perceived usefulness ($\beta = 0.168$, $p < .001$), providing evidence for H1 and H2. These results suggest that stronger audience engagement

enhances consumers' confidence in the credibility and usefulness of review information.

Perceived credibility also emerged as an important determinant of consumer evaluations. It demonstrated significant positive relationships with perceived usefulness ($\beta = 0.215, p < .001$), attitude toward purchase ($\beta = 0.248, p < .001$), and purchase intention ($\beta = 0.201, p < .001$), thereby supporting H3, H4, and H5.

Similarly, perceived usefulness significantly influenced both attitude toward purchase ($\beta = 0.201, p < .001$) and purchase intention ($\beta = 0.234, p < .001$), confirming H6 and H7. Collectively, these findings indicate that YouTube engagement metrics contribute to purchase intention by strengthening consumers' perceptions of credibility and usefulness, consistent with the Stimulus–Organism–Response (S–O–R) framework.

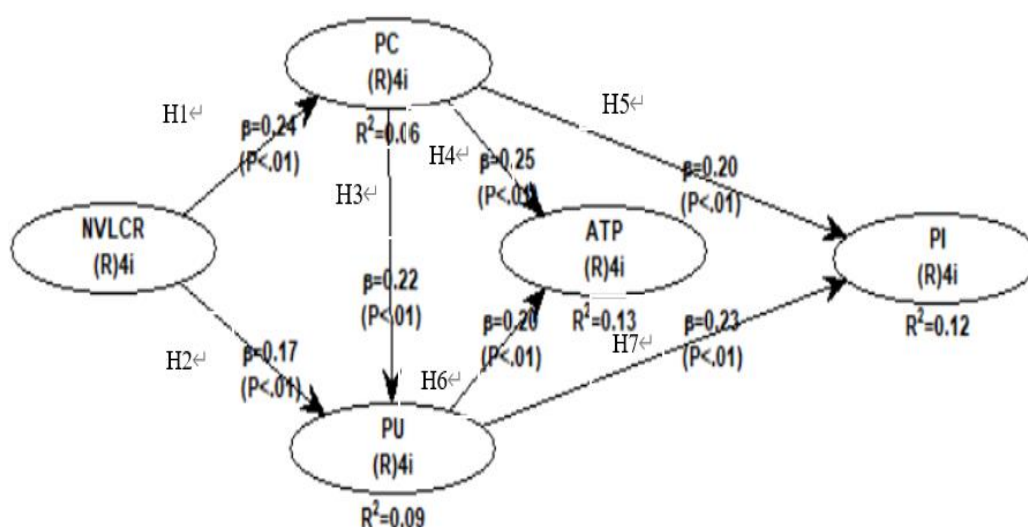


Figure 2. PLS results

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Standardized path coefficients (β) and R^2 values are reported.

9. CONCLUSION

This research provides empirical evidence that YouTube engagement metrics play a meaningful role in shaping Thai consumers' purchase intentions. The analysis demonstrates that audience interactions, represented by views, likes, comments, and replies, positively influence consumers' perceptions of credibility and usefulness. These psychological evaluations subsequently contribute to more favourable purchasing attitudes and stronger purchase intentions. The statistical findings also confirm that the proposed conceptual framework effectively

explains consumer behaviour in the context of YouTube product review videos.

In addition to verifying the proposed research model, this paper also adds to the existing body of research on digital marketing, electronic word-of-mouth and online consumer behaviour by providing data from Thailand. The findings highlight the value of incorporating engagement indicators into the Stimulus–Organism–Response (S–O–R) framework to explain purchasing behaviour in social media environments where user interaction is highly visible.

From a practical perspective, organisations and content creators should pay greater attention to encouraging meaningful audience engagement

rather than focusing exclusively on promotional content. Review videos that generate active interaction are more likely to strengthen consumers' trust in the information presented, improve product evaluations, and increase purchase intentions. These findings offer practical guidance for businesses seeking to enhance the effectiveness of YouTube as a digital marketing platform.

10. SUGGESTIONS AND RECOMMENDATIONS

The outcomes of this research provide several practical recommendations for organisations that rely on YouTube as a marketing communication platform. Rather than focusing solely on promotional messages, businesses and content creators should develop product review videos that present accurate, reliable, and useful information while encouraging meaningful audience participation through views, likes, comments, and replies. Stronger audience engagement can improve consumers' perceptions of credibility and usefulness, ultimately contributing to more favourable purchasing decisions.

This study also identifies several opportunities for future research. Future investigations may incorporate additional factors, such as source attractiveness, trust, parasocial interaction, or product involvement, To give more people a sense of how consumers behave online. Compare TikTok, Instagram and Facebook in a study to see whether the effect of engagement on the intention to purchase differs among these platforms. In addition, applying probability sampling techniques or longitudinal research designs may improve the generalisability and robustness of future findings.

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Determinants of Thai Consumers' Trust in Thailand E-Commerce Platforms

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ABSTRACT

The fast expansion of mobile commerce in Thailand has changed customer purchasing habits and increased reliance on e-commerce platforms. However, customer trust remains a significant hurdle due to the unpredictable nature of internet transactions. This study looks into the factors that influence customer trust in Thai e-commerce platforms, such as logistics performance, vendor quality, customer reviews, mobile application ease of use, and shoppertainment, and how these affect perceived security. The study used the Stimulus-Organism-Response (S-O-R) paradigm to show how external platform stimuli impact consumers' internal psychological assessments before influencing trust development. A quantitative study design was employed, with data gathered from 400 Thai customers who had previously utilized mobile shopping platforms. Structural Equation Modeling (SEM) was used to analyze the offered hypotheses, with Jamovi's SEMLj module. According to the findings, all five antecedent elements have a significant influence on perceived security, which in turn has a large impact on customer trust. Among the antecedent factors, shoppertainment had the greatest effect on perceived security. The study builds on earlier research by combining functional, technological, informational, and experiential aspects into a single framework and emphasizing the importance of perceived security in building trust. The findings have practical implications for e-commerce platform providers trying to boost client confidence in Thailand's digital economy.

Keywords:(Customer Trust, Perceived Security, Thai E-Commerce, Mobile Commerce, Shoppertainment, S-O-R Framework)

1. INTRODUCTION

The fast development of digital technology has profoundly altered the global retail industry and spurred the rise of online commerce. Rising internet penetration, widespread smartphone use, and increasing use of digital payment methods have all contributed to the growth of mobile commerce in Thailand, making online buying a necessary part of consumers' everyday lives [5]. Major platforms like as Shopee, Lazada, TikTok Shop, and LINE Shopping are always competing by offering easy

purchase options, diverse product selections, and enjoyable shopping experiences. As competition heats up, customer trust has emerged as one of the most important indicators of platform sustainability and long-term competitiveness.

Customer trust is especially important in e-commerce since transactions are more unpredictable than in traditional retail settings. Consumers are unable to physically inspect items or communicate directly with vendors before making a purchase de-

cision, generating concerns about transaction security, payment protection, product authenticity, and privacy. Previous research has repeatedly demonstrated that trust reduces customers' perceived risk and increases their willingness to do online transactions [3,8]. As a result, understanding how clients build trust has emerged as a critical study issue in e-commerce.

Previous research has identified a variety of platform-related variables that influence customer trust in online purchasing scenarios. Reliable logistics services increase delivery efficiency and minimize the uncertainty associated with online purchases [10]. Vendors who provide credible product information, responsive services, and reliable feedback mechanisms are more likely to gain customer trust [9]. Customer reviews reduce information asymmetry and help in purchasing decisions by offering authentic experiences from previous buyers [4,7]. Furthermore, mobile app usability increases user engagement with digital platforms by simplifying navigation and transaction processes [6]. Shoppertainment, which includes live streaming, gamification, and interactive shopping experiences, has recently emerged as an important element for increasing customer engagement and platform trust [11].

Although these characteristics have been extensively studied in previous studies, the vast bulk of research has focused only on their direct impact on customer trust. There has been limited research into how these operational, technological, informational, and experiential factors affect consumer trust through psychological assessments, particularly in the context of Thai e-commerce platforms. As a result, the basic mechanism of turning platform

qualities into customer confidence is still poorly understood.

To close this research gap, the current study adopts the Stimulus-Organism-Response (S-O-R) model proposed by Mehrabian and Russell [2]. The S-O-R hypothesis asserts that exterior environmental stimuli impact people's internal psychological states, which in turn drive their behavioral responses. In this study, logistics performance, vendor quality, customer reviews, mobile application ease of use, and shoppertainment are conceptualized as external stimuli (Stimuli), perceived security represents consumers' internal psychological evaluation (Organism), and customer trust is regarded as the behavioral response. This theoretical framework provides a comprehensive explanation of how platform-related issues affect trust formation in mobile commerce.

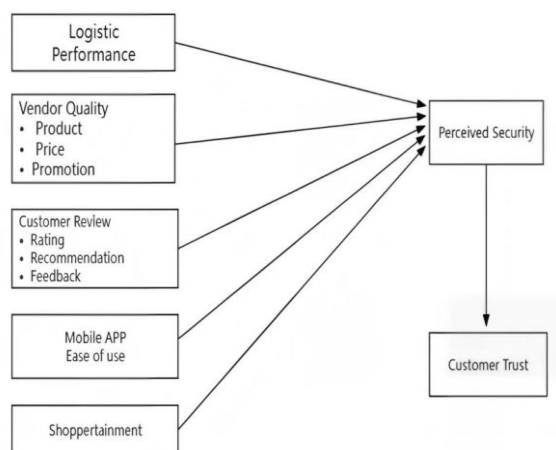
The purpose of this study is to look at the aspects that influence customer trust in Thai e-commerce platforms, especially how logistics performance, vendor quality, customer reviews, mobile application ease of use, and shoppertainment affect perceived security. Furthermore, the study uses perceived security as a mediator to better understand the link between these platform qualities and consumer trust. A quantitative study approach was employed, with survey data gathered from 400 Thai customers who had previously utilized mobile shopping. The suggested conceptual framework was tested using Structural Equation Modeling (SEM), and the links between the research elements were explored.

2. MATERIALS AND METHODS

This study employed a quantitative research approach to evaluate the elements influencing customer trust in Thai e-commerce platforms. A cross-

sectional survey was conducted to gather empirical data from Thai customers who had previously purchased products through mobile commerce platforms. The quantitative technique was used because it enables the exploration of causal links between numerous latent dimensions using Structural Equation Modeling (SEM) [1]. The proposed conceptual framework is presented in Figure 1.

Figure 1 Conceptual Framework



The target demographic was Thai customers aged 18 and up who have bought products from e-commerce platforms in the previous year. An online questionnaire was sent around social media platforms and online forums to collect data. Convenience sampling was chosen because it is appropriate for conducting online consumer research and is successful in reaching active mobile commerce customers. In all, 401 questionnaires were collected. After filtering, 400 responses were chosen for statistical analysis.

The questionnaire was divided into two pieces. The first phase gathered demographic data from respondents, while the second phase assessed the research constructs. The researchers used seven latent variables: logistics performance (LP), vendor quality (VQ), customer reviews (CR),

mobile application ease of use (EU), shoppertainment (ST), perceived security (PS), and customer trust (CT). All assessment questions were based on existing research on e-commerce and customer behavior. Responses were scored on a five-point Likert scale, with 1 indicating strong disagreement and 5 indicating strong agreement.

The data was assessed in Jamovi using the SEM module. Structural Equation Modeling (SEM) was used to validate the study model.

3. RESULTS AND DISCUSSION

A total of 401 surveys were collected from Thai consumers who had previously used mobile commerce platforms. Following data screening, 400 valid replies were chosen for statistical analysis. TikTok Shop had the highest demographic share (44.9%), followed by Lazada (23.9%), Shopee (20.2%), and LINE Shopping (11.0%). Male respondents comprised 82.5% of the sample, with the largest age group lying between 41 and 50 years old (56.1%). The majority of respondents (68.1%) held a bachelor's degree, and more than half reported monthly incomes ranging from 30,000 to 60,000 Baht (56.6%). Furthermore, more than half of respondents (54.9%) reported using mobile commerce platforms practically every day, demonstrating a strong interest in online purchasing. Since convenience sampling was employed, the demographic distribution of respondents may not fully represent the general population of Thai e-commerce users. Future studies should employ probability sampling techniques and recruit a more balanced sample across gender and age groups to improve generalizability.

Table 1 Fitting index

	Criteria	Value	Result
CFI	> 0.9	0.945	Good

TLI	> 0.9	0.939	Good
RMSEA	< 0.05	0.046	Good

Table 1 presents the goodness-of-fit indices of the measurement model. The results indicate that the model achieved a satisfactory fit with the observed data. Specifically, the Comparative Fit Index (CFI = 0.945) and Tucker–Lewis Index (TLI = 0.939) both exceeded the recommended threshold of 0.90, while the Root Mean Square Error of Approximation (RMSEA = 0.046) was below the recommended threshold of 0.05. These findings confirm that the proposed measurement model demonstrated an acceptable level of model fit and was appropriate for subsequent structural equation modeling analysis.

Table 2 Reliability Test

Construct	Items	Cronbach's alpha coefficient
400 Sample	41	0.831
LP	5	0.802
VQ	5	0.817
CR	5	0.825
ST	5	0.849
EU	5	0.846
PS	5	0.852
CT	5	0.871

Table 2 presents the reliability analysis of all measurement constructs. Cronbach's alpha coefficients ranged from 0.802 to 0.871, which are all above the recommended threshold of 0.70. These findings indicate satisfactory internal consistency and demonstrate that all constructs are reliable and suitable for further statistical analysis.

Table 3 Matrix Factor Loading Analysis

Latent Fact	Factor loading	CR	AVE
LP		0.777	0.467
LP1	0.611		
LP2	0.674		
LP3	0.748		
LP5	0.722		
VQ		0.788	0.481
VQ1	0.700		
VQ2	0.680		
VQ3	0.712		
VQ4	0.715		
CR		0.765	0.450
CR2	0.710		
CR3	0.690		
CR4	0.652		
CR5	0.666		
EU		0.827	0.490
EU1	0.746		
EU2	0.720		
EU3	0.705		
EU4	0.713		
EU5	0.694		
ST		0.826	0.544
ST1	0.778		
ST2	0.706		
ST3	0.729		
ST5	0.734		
PS		0.855	0.541
PS1	0.714		

Latent Fact	Factor loading	CR	AVE
PS2	0.712		
PS3	0.743		
PS4	0.749		
PS5	0.748		
CT		0.881	0.598
CT1	0.756		
CT2	0.745		
CT3	0.749		
CT4	0.756		
CT5	0.795		

Table 3 reports the factor loadings, composite reliability (CR), and average variance extracted (AVE) of each construct. All standardized factor loadings exceeded 0.60, indicating satisfactory indicator reliability. Composite reliability values ranged from 0.765 to 0.881, exceeding the recommended threshold of 0.70. Although the AVE values of Logistics Performance, Vendor Quality, Customer Reviews, and Ease of Use were slightly below the recommended threshold of 0.50, their composite reliability values remained above 0.70. According to Fornell and Larcker (1981), convergent validity can still be considered acceptable when composite reliability is adequate. Therefore, all constructs were retained for subsequent SEM analysis.

Table 4 SEM – Measurement Model Test

Hypothesis	Path	β	Z-value	P-value	Result
H1	LP→PS	0.142	2.314	.021	Supported
H2	VQ→PS	0.198	2.876	.004	Supported
H3	CR→PS	0.356	4.921	<.001	Supported
H4	EU→PS	0.241	3.587	<.001	Supported
H5	ST→PS	0.402	5.638	<.001	Supported

Table 4 summarizes the hypothesis testing results of the structural model. All five proposed hypotheses were statistically supported. Shoppertainment showed the strongest positive effect on Perceived Security ($\beta = 0.402$, $p < 0.001$), followed by Customer Reviews ($\beta = 0.356$, $p < 0.001$). Mobile Application Ease of Use ($\beta = 0.241$, $p < 0.001$), Vendor

Quality ($\beta = 0.198$, $p = 0.004$), and Logistics Performance ($\beta = 0.142$, $p = 0.021$) also had significant positive effects on Perceived Security. These findings indicate that all proposed antecedents significantly contribute to consumers' perceived security in Thai e-commerce platforms.

Table5 Indirect Effects of Structural Model (Bootstrap 5000)

Hypothesis	Path	β	Bootstrap SE	95% CI	P-value	Result
H7a	LP→PS→CT	0.095	0.038	(0.021,0.168)	.021	Supported
H7b	VQ→PS→CT	0.132	0.041	(0.052,0.211)	.001	Supported
H7c	CR→PS→CT	0.238	0.049	(0.142,0.334)	<.001	Supported
H7d	EU→PS→CT	0.161	0.043	(0.076,0.246)	<.001	Supported
H7e	ST→PS→CT	0.269	0.052	(0.168,0.371)	<.001	Supported

Table 5 presents the bootstrapping results of the indirect effects. The analysis confirmed that Perceived Security significantly mediated the relationships between all antecedent variables and Customer Trust. Among the indirect effects, Shoppertainment demonstrated the strongest mediating effect ($\beta = 0.269$), followed by Customer Reviews, Ease of Use, Vendor Quality, and Logistics Performance. These findings further support the mediating role of Perceived Security in transforming platform characteristics into customer trust.

4.CONCLUSIONS

This study employed the Stimulus-Organism-Response (S-O-R) paradigm to investigate the elements that impact consumer trust in Thai e-commerce platforms. The findings revealed that logistical performance, vendor quality, customer reviews, mobile application ease of use, and shoppertainment all had a significant positive impact on perceived security, leading in greater consumer trust.

Among the criteria studied, shoppertainment had the highest influence on perceived security, followed by customer feedback. These findings suggest that secure transactions and engaging shopping experiences are essential for building customer trust in Thai e-commerce platforms. The study extends the application of the S-O-R framework to the

Thai e-commerce context and highlights the mediating role of perceived security. Practically, e-commerce platforms should improve logistics services, vendor management, review systems, application usability, and interactive shopping features to enhance customer confidence.

This study has several limitations. The findings are based on cross-sectional data collected from Thai consumers and may not be generalizable to other contexts. Future research should employ longitudinal designs, include broader samples, and examine additional factors that may influence customer trust.

5.THEORETICAL CONTRIBUTIONS

This study contributes significantly to online customer behavior and e-commerce research. First, it broadens the literature by merging the S-O-R paradigm with perceived risk theory, resulting in a comprehensive framework tailored to mobile commerce. While earlier research has frequently shown trust as a direct, simultaneous consequence of multiple platform qualities, this study adopts a process-oriented approach. It demonstrates how Perceived Security acts as a basic cognitive mediator (Organism), transforming multiple operational, technical, and experiential information into a unified psychological sensation of safety before the creation of behavioral trust. Second, this study broadens the typical use of the S-O-R paradigm by including Shopertainment as an experience stimulant in addition to standard utilitarian criteria such as ease of use. This structural change highlights the increased significance of hedonic engagement and live interaction in shaping a user's cognitive judgment of digital safety and platform integrity.

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The Impact of Inclusive Leadership on Employees' Adaptive Performance: The Mediating Roles of Psychological Capital

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Abstract: Grounded in Self Determination Theory (SDT), this paper explores whether or not the psychological capital of employees can be connected to the outcomes of adaptive performance and inclusive leadership. The objectives of study are first, to close the aforementioned gaps in the research second, to examine how an inclusive leadership style affects employees' psychological capital third, how psychological capital affects adaptive performance and lastly to determine whether the psychological capital of employees may link inclusive leadership to adaptive performance. Survey data were obtained from 139 workers from 45 private organizations in Thailand who work in various positions. The hypotheses were evaluated by using the partial least-squares structural equation type of modeling. The key quantitative finding results not only supported the positive association between inclusive leadership and psychological capital, but also the positive association between psychological capital and adaptive performance. Moreover, the result of the mediating effect found that the psychological capital of employees fully connected the association between inclusive leadership and adaptive performance. This study provides a theoretical explanation and evidence to clarify why employees may require psychological capital for the purpose of bringing inclusive leadership to their adaptive performance.

Keywords: adaptive performance, inclusive leader, psychological capital

1. INTRODUCTION

The economic recession and geopolitical conflicts have had a tremendous impact on businesses worldwide. To ensure the survival of their companies during the crisis, several business owners used corporate reorganization and cost-cutting strategies. A lot of businesses need to reduce the number of employees and leave only talented employees who have the skills to perform various tasks. While many organizations must reduce their employees because of the economic situation, highly talented employees could feel exhausted as a result of the duties' greater complexity and

requirement for a wider range of abilities. Employees have to have resilience in order to perform multitasks assigned by the leaders, which are sometimes not their familiar tasks. In this particular situation, not all of these employees can adapt themselves to the extra assignments that they need to do. Therefore, the research questions that require answering in this study are whether the leadership's style and employee's own characteristics actually facilitate employee's adaptive performance after the organization is restructured.

Employees' ability to adapt in the workplace is influenced by leadership styles as well (1).

To foster this ability, leaders must offer their employees both functional and emotional assistance (2,3). In recent years, academics have paid increased attention to inclusive leadership style. There are still some gaps to be filled, though. First, although the impact of the inclusive leadership style on employees' psychological capital has been well documented in the literature, there are currently very few studies that examine what sort of impact psychological capital might have on adaptive performance. Secondly, another research gap area is the potential mediation role of psychological capital in linking the connection between inclusive leadership style and employees' adaptive performance. Only a small number of research have offered support for this claim thus far. Given the small number of studies, it's critical to identify the employee characteristics and leadership styles that may be crucial for fostering adaptive performance.

2. RESEARCH OBJECTIVES

- ☐ To close the aforementioned gaps in the research.
- ☐ To examine how an inclusive leadership style affects employees' psychological capital and how psychological capital affects adaptive performance.
- ☐ To determine whether the psychological capital of employees may link inclusive leadership to adaptive performance.

3. RESEARCH HYPOTHESIS

H1: There is a positive association between inclusive leadership and psychological capital.

H2: There is a positive association between psychological capital and adaptive performance.

H3: Psychological capital plays a mediating role between inclusive leadership and adaptive performance.

4. CONTRIBUTION

No studies have looked at psychological capital in terms of being a mediator that might connect the association between inclusive leadership and adaptive performance, despite prior research showing a positive correlation between psychological capital and inclusive leadership (4). The self-determination theory (SDT) proposes that

there is a desire that people feel to be connected with their group members as well as to act in accordance with their integrated sense of self; Deci and Ryan (5) has been incorporated into the study. This demonstrates that the traits of employees who possess psychological capital appear to be consistent with the tenet of the self-determination theory (SDT). The study also contributes to this theory by elucidating why employees might require to have psychological capital to undertake tasks, even taxing ones, with a positive attitude and to adjust their performance to the specifics of the tasks that their managers and

teammates expect from them. The study builds on the data from past studies, which fell short in their theoretical understanding of specific border situations that could limit the benefits of an inclusive leadership style. This study also highlights the fact that inclusive leadership may not always be beneficial to adaptive performance; adaptive performance also depends on the psychological capital of the individual employee.

This study also offers a useful practical contribution to organizations that intend to restructure their firm and cost-cutting by giving existing staff members additional responsibilities. Leaders must assist employees in building psychological capital so they can carry out their duties successfully in a variety of circumstances; this also facilitates employees' ability to overcome challenges and enhance their adaptive performance. In addition, during the particular situation in the organization,

leaders need to provide both functional and emotional support to their employees in order to facilitate them to perform their tasks effectively. Indeed, this recommendation is consistent with Yu (6), who claims that inclusive leadership produces adaptive performance from employees through the function of learning orientation and so significantly enhances the operational efficiency and performance of organizations. Additionally, as employees' psychological capital grows, they will be better able to handle the uncertainty and difficulties of complex tasks.

5. CONCEPTUAL FRAMEWORK

The conceptual framework of this study, depicting the hypothesized relationships among inclusive leadership, psychological capital, and adaptive performance, is presented in Figure 1.

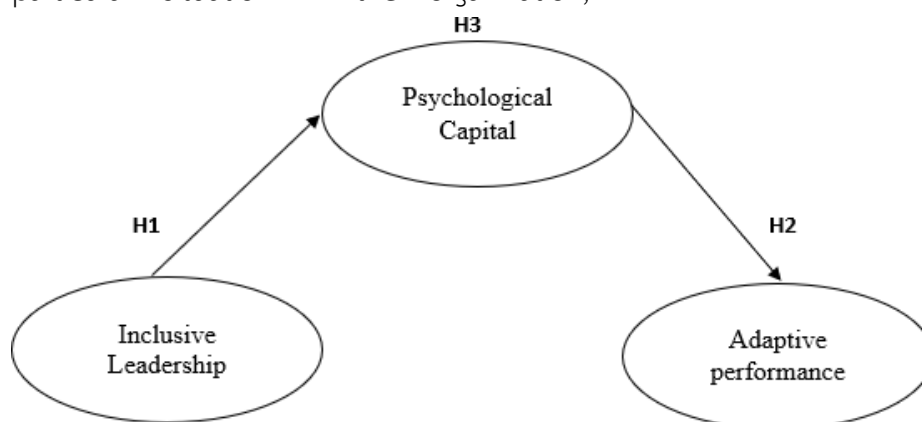


Figure 1. Conceptual framework of the study

6. THEORIES AND LITERATURE REVIEWS

The impact of leadership style on performance

Because leaders play a critical role in motivating and enhancing employee performance, the leadership style has an impact on employee productivity (7,8). Even so, having a good leadership style alone does not ensure that an employee will perform well. Although a leader's approach might have an impact on their team members, those who lack the skills to take on demanding tasks will feel the impact less. Employees generally have more confidence and expectations for doing additional and new responsibilities when leaders exhibit an open, approachable attitude toward them, which allows them to effectively change their performance (4).

Theoretically speaking, the self-determination concept can explain this phenomenon (5). According to Deci and Ryan (5), the need of group members to experience a feeling of connection to those around them, in addition to behaving in a way which complements an individual's integrated sense of self, is clear and real. Being a part of a community and feeling its warmth is the definition of belonging, whereas being authentic indicates that a group encourages each member to feel and

behave in line with their actual selves (9). Chiu (10), based on self-determination theory, a study on students' motivation for artificial intelligence (AI) as a class from kindergarten right through to the twelfth grade discovered that students' perceptions of learning processes have an impact on their motivation and engagement in class, which in turn increases their confidence in learning. In particular, the evidence based on self-determination theory implies that individuals with positive perception and attitude towards their challenging tasks can gain more benefit from inclusive leadership styles and better achieve adaptive performance.

7. RESEARCH METHODOLOGY

This study sample was an employee who had to perform multiple tasks after the organization's restructuring due to cost cutting. The sample was drawn from 45 private companies in Thailand. Due to the economic recession, these organizations need to downsize the number of their employees. Existing employees need to perform more responsible tasks and learn how to perform unfamiliar tasks. Thus, they are a suitable sample for this research that focuses on the obstacles that employees face in performing their routines and new challenging tasks. The survey was conducted using an online questionnaire created by Google Form. The researcher was the one who sent the link of the questionnaire to this group of employees. There were 200

employees from 45 private organizations in Thailand to whom the author sent the link of the questionnaire the respondents work in various positions of these 45 organizations. After the period of data collection was over, which means the end of May 2026, we received a total of 139 usable survey responses, an approximately 70 percent response rate from all 200-questionnaire links that research sent.

For the measurement scales of the three concepts of independent variable, mediating variable, and dependent variable, the author applied these scales: Inclusive leadership was measured with the scale Carmeli et al. (11) developed. Psychological capital was gauged on the scale Luthans et al. (12) developed. Adaptive performance was measured on the scale Koopmans et al. (13) developed. All the questions were scored on a Likert scale (from one to five). As well as the key independent variables hypothesized to affect adaptive performance, we incorporated certain control variables that might also affect adaptive performance in the model estimation, especially the participants' age, gender, and marital status. Gender and marital status were coded as categorical variables (male = 1; female = 0) and (single = 1; marriage = 0).

Analyzing the data in part to test the hypotheses using the model estimation,

partial least squares structural equation modeling (PLS-SEM) was utilized. This was carried out using WarpPLS version 8, which was employed to carry out the PLS-SEM

8. RESULT

To ensure that the psychometric quality of the latent constructs matched the requirements, some preliminary tests were carried out. All of the latent constructs showed acceptable convergent validity, which was determined by factor loadings, which must be more than .5. Comparing a latent variable's square root of average variance extracted (AVE) with its correlations with other constructs is important to evaluate discriminant validity. For AVE to have discriminant validity, its square root must be larger than those of other associations. All latent variables passed the discriminant validity test, according to Table 1's findings. The composite reliability coefficient and Cronbach's alpha coefficient, both of which should be greater than .7, were then utilized as markers to evaluate construct dependability. The coefficients for each of the latent constructs met the reliability requirement, as shown in Table 1. The entire variance inflation factor (VIF) statistics, which should be less than 3.3, were also used to assess multicollinearity. The test demonstrated that multicollinearity was not a problem and that the whole VIF score ranged from 1.10 to 2.04.

Table 1. Correlations, Multicollinearity, and Divergent Validity Indicators

Variable	Cronbach's Alpha coefficient	Composite Reliability coefficient	Full Variance Inflation Factor	ICL	PC	ADAP	AGE	GEN	STATUS
ICL	.982	.984	1.682	(.92)	.457**	.089	.012	-.204	-.179
PC	.943	.967	1.942		(.804)	.238*	-.025	.210	-.276***
ADAP	.784	.799	1.107			(.695)	.112	.052	-.078
AGE	-	-	2.042				(1)	.438*	-.779
GEN	-	-	1.899					(1)	-.570
STATUS	-	-	1.788						(1)

Notes: ***p < 0.001, **p < 0.01, *p < 0.05.

Square roots of average variance extracted of latent variables are shown in the parentheses. ICL = inclusive leadership, PC = psychological capital, ADAP = adaptive performance, AGE = age, GEN = gender (male = 1; female = 0), STATUS = marital status (Marriage = 1; Single = 0).

The PLS results, which represent the outcomes of all hypothesis testing, are shown in Figure 2. According to Hypothesis 1, inclusive leadership is positively correlated with psychological capital. The beta coefficients that characterize their correlations suggest that inclusive leadership and psychological capital are positively correlated, as seen in Figure 2 ($\beta = .62$; $p < .01$). The second hypothesis suggests that psychological capital is positively correlated with adaptive performance. The beta coefficients that describe their relationships suggest that psychological capital and adaptive performance are positively correlated, as illustrated in Figure 2 ($\beta = .33$; $p < .01$). Additionally, this study investigates

whether the contribution of inclusive leadership can be linked indirectly to adaptive performance through the mediating function of psychological capital in connection to the relationship in Hypotheses one and three. To assess the mediating impact, the researcher applied WarpPLS 8.0's indirect effects analysis and total effects analysis. According to the analysis's findings (Figure 2), there is an indirect, positive relationship concerning inclusive leadership and adaptive performance that is mediated by psychological capital ($\beta = .20$; $p < .001$). To evaluate the contribution of inclusive leadership on adaptive performance by accounting for all the conduits that join both these variables, this research also conducted

a total effects analysis in addition to the indirect effects study. The analysis supported the psychological-capital-connected overall beneficial effect of inclusive leadership on adaptive performance ($\beta = .20$; $p < .001$). These findings suggest that inclusive leadership alone is insufficient for fostering

improved adaptive performance among employees. The findings imply that psychological capital is a crucial aspect that helps to explain why individuals who work for firms with inclusive leadership typically do better in adaptive performance. As a result, this mechanism of inclusive leadership can help employees perform more adaptively.

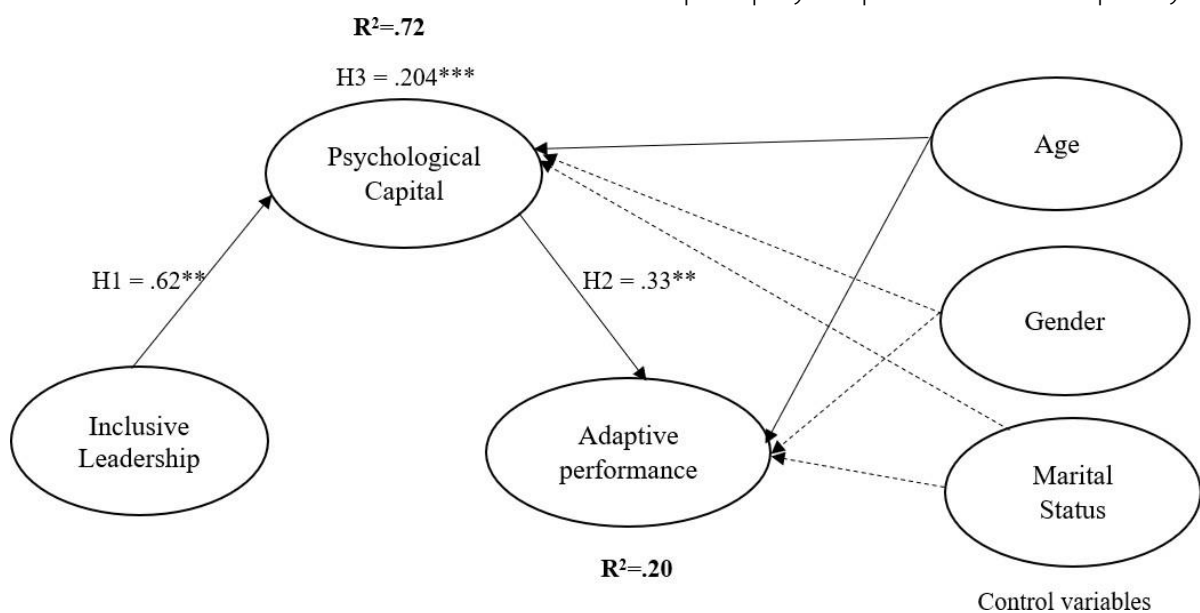


Figure 2. PLS results

Notes: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Standardized coefficients are reported.

Dashed lines represent the non-significant results.

9. CONCLUSION

In this study, psychological capital serves as a mediator as we look at the impact of inclusive leadership on adaptive performance. First off, the analysis amply supports the notion that there is a positive correlation between psychological capital and inclusive leadership. This complements the finding of previous research, which has shown that inclusive leadership helps

employees build psychological capital so they can successfully adapt to their tasks (4,14). The analysis shows that psychological capital not only had an association, both significant and positive, with adaptive performance but also significantly linked the positive relationship of inclusive leadership and adaptive performance with respect to the given hypotheses involving psychological capital and the mediating effect. These findings are in line with earlier studies on the

beneficial association that psychological capital has with adaptive performance as well as the mediator function of psychological capital in increasing employee engagement and performance outcomes (15,16).

10. SUGGESTIONS AND RECOMMENDATIONS

The recommendation is for the creation of a new, inclusive leadership style and for business human resource management. The end result provides leaders with good counsel on the way to go about the adoption of a style of leadership that can fit the traits of the next generation of employees, fully exploit their advantages, and foster their adaptive performance to support corporate performance outcomes. Leaders should prioritize building employees' psychological capital in addition to their leadership style in order to increase the benefits and value of the company that arise from employees' adaptive performance (16).

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A pilot study of post-graduate students' perceptions of using artificial intelligence tools

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ABSTRACT

This pilot study examined post-graduate students' perceptions of AI tools using the Technology Acceptance Model (TAM), focusing on perceived usefulness (PU), perceived ease of use (PEOU), and behavioral intention (BI) in academic contexts. Post-graduate students represent an understudied population in AI acceptance research, yet their perceptions are particularly relevant for program development and institutional AI strategy. A quantitative survey collected data from 20 post-graduate students enrolled in an international Masters in Education program at Rajamangala University of Technology Krungthep, Bangkok, Thailand, using validated TAM instruments across three dimensions on 5-point Likert scales. Supplementary informal discussion with all participants provided additional qualitative context. Data were analyzed using descriptive statistics, one-sample t-tests, and correlation analysis. Students demonstrated overwhelmingly positive perceptions across all TAM dimensions. Perceived ease of use scored highest ($M = 4.20$), followed by behavioral intention ($M = 4.06$) and perceived usefulness ($M = 4.02$). All means were significantly above the conservative neutral threshold of 3.40 ($p < .01$). Strong positive correlations emerged between perceived usefulness and behavioral intention ($r = .890$), perceived ease of use and behavioral intention ($r = .852$), and perceived ease of use and perceived usefulness ($r = .802$). Informal discussions revealed that while students were generally comfortable using AI tools, they held reservations about accuracy, whether they were maximising the tools' potential, and broader implications for education. These findings provide preliminary empirical support for TAM's applicability in the AI context among post-graduate learners and offer actionable insights for Masters program curriculum development and institutional AI integration strategies.

Keywords: artificial intelligence, technology acceptance model, post-graduate students, pilot study

1. INTRODUCTION

The rapid advancement of artificial intelligence (AI) technologies has significantly reshaped higher education, introducing new possibilities for teaching, learning, and academic administration. AI-driven tools such as ChatGPT, Gemini, Claude, and DeepSeek have gained increasing attention for their ability to assist students in completing academic tasks, generating content,

answering questions, and supporting autonomous learning. As educational institutions consider integrating these tools into academic environments, understanding how students perceive them in terms of usefulness, ease of use, and adoption intention becomes essential.

Existing literature indicates generally positive perceptions of AI tools among university students across various disciplines

(Yilmaz et al., 2023; Das & Madhusudan, 2024). However, the substantial majority of this research has focused on undergraduate populations, leaving post-graduate students — who engage with AI in qualitatively different ways, with greater academic independence and professional stakes — comparatively understudied. This gap is significant: post-graduate students are more likely to use AI tools for research, thesis writing, and professional development, and their perceptions carry direct implications for program design and graduate-level pedagogy.

Furthermore, concerns about accuracy, ethical implications, and whether users are genuinely maximising AI capabilities continue to shape how students evaluate these systems (Amaro et al., 2023; Asirit & Hua, 2023). Despite growing discussion, relatively few studies have examined how PU, PEOU, and BI specifically shape post-graduate students' acceptance of AI tools in academic contexts, and fewer still have been conducted within international postgraduate programs in Southeast Asia.

This pilot study addresses that gap by exploring post-graduate students' perceptions of AI tools through the TAM framework, within a Masters in Education program at Rajamangala University of Technology Krungthep (RMUTK), Bangkok, Thailand. As a pilot study with a small but complete cohort, the findings are intended to generate preliminary evidence, inform instrument refinement, and provide an empirical basis for program-level decisions

regarding AI integration — with the explicit aim of scaling to a larger multi-institution study.

While AI tools are becoming increasingly embedded in academic settings, empirical data on how post-graduate students specifically perceive their usefulness, ease of use, and likelihood of continued use remains limited. Research has largely focused on general student attitudes or undergraduate populations, with less emphasis on the behavioral predictors that influence adoption among advanced learners whose academic and professional needs differ substantially.

Post-graduate students occupy a unique position: they are expected to work with greater autonomy, engage critically with emerging tools, and produce research-level outputs. Yet this population has received disproportionately little attention in the AI acceptance literature. Without focused analysis of PU, PEOU, and BI among post-graduate learners, program administrators and curriculum designers lack the evidence needed to develop targeted, effective AI integration strategies at the graduate level.

This study addresses that gap through a structured quantitative approach supplemented by informal discussion, within an international postgraduate program in Thailand — a context that adds both cultural and linguistic dimensions to AI perceptions that remain underexplored in the literature.

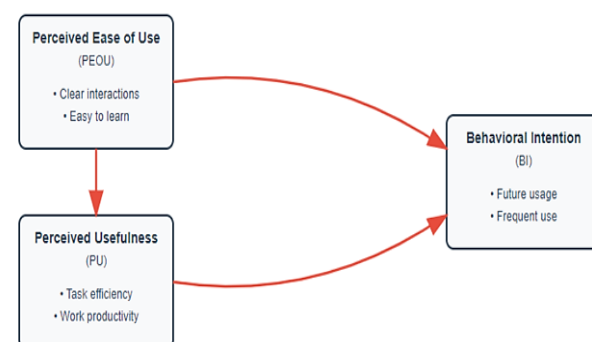
This study holds direct relevance for program coordinators, curriculum designers, and institutional policymakers seeking to integrate AI responsibly into postgraduate education. By evaluating Masters students' perceptions through TAM, the research offers practical, program-specific insights into how and why advanced students are likely to adopt AI tools — and where reservations persist.

For the RMUTK Masters in Education program specifically, the findings offer an evidence base for decisions about curriculum design, AI literacy training, and student support structures. More broadly, by contributing pilot data on an understudied population in an international program context, the study supports the development of more targeted and inclusive AI implementation strategies across institutions. Understanding post-graduate students' behavioral intentions and concerns — including reservations about accuracy and the educational implications of AI — enables programs to position AI as an augmentative academic tool rather than a source of uncertainty.

Research Objectives

1. To assess post-graduate students' perceived usefulness (PU) of AI tools in academic tasks.

2. To evaluate post-graduate students' perceived ease of use (PEOU) of AI as a learning and productivity tool.
3. To examine the behavioral intention (BI) of post-graduate students to use



AI for academic and professional purposes.

4. To generate pilot data that can inform AI integration within the Masters in Education program and provide a foundation for larger-scale follow-up research.

Conceptual Framework

The study applies the Technology Acceptance Model (TAM) to the context of AI tool adoption among post-graduate students. TAM proposes three core relationships: first, that Perceived Ease of Use directly influences Behavioral Intention; second, that Perceived Usefulness has a direct effect on Behavioral Intention; and third, that Perceived Ease of Use influences Perceived Usefulness — suggesting that when students find AI tools easy to use, they are more likely to perceive them as useful. The model posits that behavioral intention, as the primary outcome

variable, predicts actual usage behavior and is jointly determined by utility and usability perceptions. This framework provides the theoretical foundation for understanding the key factors driving post-graduate student acceptance of AI technologies, and for identifying where program-level support may be most needed (see Figure 1).

Figure 1. The diagram shows the relationship between the variables.

Literature Review

Yilmaz, Maxutov, Baitekov, and Balta (2023) developed and validated an instrument for measuring university students' perceptions of ChatGPT among 239 students in Kazakhstan, finding overall positive perceptions. Notably, prior experience with AI produced significant differences across almost all TAM dimensions, underlining the importance of exposure and familiarity — a factor directly relevant to program-level training decisions.

Das and Madhusudan (2024) explored 162 higher education students' perceptions of ChatGPT's academic utility, reporting generally positive views and finding that gender, academic program, and academic stream did not significantly influence perceptions. This consistency across demographic variables suggests that positive AI perceptions may be relatively robust, though the study's undergraduate focus limits direct applicability to post-graduate contexts.

Kumar and Raman (2022) collected data from 682 business management students and found that while students believed AI could be effectively used in teaching and academic administration, they expressed reservations about its use in higher-stakes processes such as admissions and examinations. This nuanced acceptance — broadly positive but contextually qualified — mirrors patterns observed in the present study.

Nouraldeen (2023) investigated AI adoption among 330 accounting students at Lebanese universities, finding that technology readiness and perceived usefulness positively affected adoption, while perceived ease of use showed no significant independent impact. Gender moderated several relationships, with males more likely to adopt AI. These findings suggest that the relative weight of TAM constructs may vary across populations and disciplines, reinforcing the value of population-specific pilot data.

Amaro et al. (2023) demonstrated that early exposure to AI-generated misinformation significantly reduced student trust and satisfaction, even when overall usability scores remained high. This finding is particularly relevant to the present study's informal discussion data, in which students expressed concerns about AI accuracy — suggesting that trust and accuracy concerns may coexist with positive usability perceptions.

Asirit and Hua (2023) found that students' AI familiarity was influenced by age, academic year, and field of study, and identified concerns about job displacement, data privacy, and over-reliance on technology as recurring themes. The authors emphasised the need for structured AI education programs addressing both technical competencies and ethical implications — a recommendation directly applicable to Masters program curriculum design.

Laínez et al. (2024) examined 665 students' perceptions of AI for autonomous learning, finding generally favourable views while identifying challenges in fully leveraging AI's potential. Their emphasis on strengthening digital competencies resonates with the present study's finding that students lack confidence in independent AI usage.

Yasin (2022) found that while students possessed practical AI skills, their conceptual understanding remained limited, with perceptions shaped by media narratives rather than informed engagement. The combination of surface-level usability confidence with deeper uncertainty about AI capabilities and implications — a pattern visible in the present data — highlights the need for structured critical AI literacy within postgraduate curricula.

2. MATERIALS AND METHODS

This study employed a quantitative descriptive research design using a structured questionnaire as the primary data collection instrument, supplemented by informal

discussion with all participants. The aim was to explore post-graduate students' perceptions of AI tools based on three TAM constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Behavioral Intention to Use (BI). The TAM has been shown to be reliable and valid.

The study is explicitly positioned as a pilot study. The participant population comprised the complete cohort of 21 Chinese post-graduate students enrolled in the Masters in Education (International Program) at Rajamangala University of Technology Krungthep, Bangkok, Thailand. All students were invited to participate, yielding 21 distributed questionnaires and 20 useable returns — a 95.2% response rate. One questionnaire was excluded as the respondent marked 3 for all items, indicating non-engagement rather than a genuine neutral response. The small sample size is an acknowledged limitation of the pilot scope; however, the near-complete cohort capture ensures the data is representative of this specific program population, and the findings are intended to inform both program-level decisions and the design of a larger follow-up study.

Data were collected using a bilingual (English-Chinese) questionnaire measuring three variables: Perceived Usefulness — 6 items; Perceived Ease of Use — 6 items; and Behavioral Intention to Use — 5 items. Each item used a 5-point Likert scale from (1) Strongly Disagree to (5) Strongly Agree. The bilingual format ensured accessibility for

participants whose first language is Chinese. Cronbach's Alpha reliability was .96, indicating high internal consistency. Face validity was checked by 3 experts. Questionnaires were distributed and completed in person over a one-week period. All participants were informed of the study's purpose, their right to withdraw, and the confidentiality of their responses, and consent was obtained from all participants. Following questionnaire completion, informal interviews and group discussion were conducted with all students to gather supplementary qualitative context. These discussions were not formally coded but informed the interpretation of quantitative findings. Data were analysed using SPSS. Descriptive statistics (means, standard deviations) summarised responses for each variable. One-sample t-tests compared construct means against a conservative neutral threshold of 3.40 — a value set above the scale midpoint of 3.0 to apply a more stringent standard for identifying genuinely positive perceptions. Pearson correlations examined relationships between constructs.

3. RESULTS AND DISCUSSION

Tables 1 through 3 present the item-level descriptive statistics for each TAM construct.

Table 1: Perceived Usefulness

Item	Mean	SD
I find AI tools to be useful in my work.	4.1	0.72

Item	Mean	SD
Using AI tools enables me to accomplish tasks more quickly.	4.15	0.67
Using AI tools would improve my job performance.	3.8	1.01
Using AI tools would increase my productivity.	4.05	0.83
The AI tools would be useful for my daily tasks.	4.1	0.85
I believe AI tools are valuable for my work.	3.9	0.79

Table 2: Perceived Ease of Use

Item	Mean	SD
My interaction with AI tools is clear and understandable.	4.25	0.79
It is easy for me to become skillful at using AI tools.	4.15	0.88
I find AI tools easy to use.	4.35	0.75
I find it easy to learn how to use AI tools.	4.25	0.78
My interaction with AI tools is effortless.	4.25	0.72
I feel confident in using AI tools without external help.	3.95	1.10

Table 3: Behavioral Intention

Item	Mean	SD
I intend to use the AI tools frequently.	4.2	1.06
I plan to use the AI tools in the future.	4.2	0.95
I will use the AI tools whenever available.	3.95	1.05

Item	Mean	SD
I would highly recommend the AI tools to others.	3.9	0.91
I plan to use the AI tools for my work.	4.05	1.05

The overall mean for Perceived Usefulness was 4.02, significantly above the conservative neutral threshold of 3.40 ($t = 4.02$, $df = 19$, $p = .001$). Perceived Ease of Use mean was 4.20, significantly above 3.40 ($t = 5.20$, $df = 19$, $p = .001$). Behavioral Intention mean was 4.06, significantly above 3.40 ($t = 3.31$, $df = 19$, $p = .004$). Strong positive correlations were found between all three construct pairs: perceived ease of use and perceived usefulness ($r = .802$), perceived usefulness and behavioral intention ($r = .890$), and perceived ease of use and behavioral intention ($r = .852$).

Across the three dimensions, students showed highest agreement with the general ease of use item ($M = 4.35$) and task completion efficiency ($M = 4.15$), while expressing comparatively lower confidence in independent usage ($M = 3.95$) and in AI's contribution to job performance improvement ($M = 3.80$, $SD = 1.01$ — the highest variability of any item).

Informal discussions with all 20 participants provided important qualitative context for these quantitative patterns. Students reported being generally comfortable using AI tools in their studies, but expressed two consistent reservations: concern about the accuracy of AI-generated

content, and uncertainty about whether they were fully exploiting the tools' capabilities. Several students also voiced broader concerns about the future role of AI in education — including questions about academic integrity, over-reliance, and what skills students genuinely need to develop themselves. These themes enrich the interpretation of the quantitative findings and point toward specific areas where program-level support is warranted.

This pilot study examined post-graduate students' perceptions of AI tools through the TAM framework, within an international Masters in Education program. The findings provide preliminary evidence of strong, positive AI perceptions among this population, while surfacing specific areas of uncertainty with direct implications for program development.

All three TAM dimensions recorded means above 4.0 and were statistically significant against the conservative 3.40 threshold, indicating genuine positive attitudes rather than mere indifference. These findings are consistent with broader literature documenting favourable student perceptions of AI in higher education (Das & Madhusudan, 2024; Yilmaz et al., 2023), and extend those findings to a post-graduate population that has received comparatively little dedicated attention. Post-graduate students engage with AI under different conditions — greater academic autonomy, more complex writing tasks, professional development goals — and their acceptance

patterns may differ meaningfully from undergraduates.

The strong intercorrelations between TAM constructs ($r = .802$ to $.890$) support the model's applicability in the AI context. The particularly strong relationship between perceived usefulness and behavioral intention ($r = .890$) reinforces TAM's central proposition that utility perceptions are the primary driver of adoption intentions, suggesting that AI tools may constitute an unusually coherent technology experience where ease of use, usefulness, and adoption intention are tightly aligned.

Perceived ease of use scored highest overall ($M = 4.20$), reflecting the significant interface improvements of contemporary conversational AI. However, the lowest score within this dimension — confidence in using tools without external help ($M = 3.95$, $SD = 1.10$) — is telling. The relatively high standard deviation indicates meaningful variability, resonating with Yasin's (2022) observation that practical AI skills can coexist with limited conceptual understanding. Informal discussion confirmed this pattern: students felt comfortable using AI but expressed uncertainty about whether they were using it effectively. This suggests AI literacy training should go beyond tool introduction to address effective prompting, output evaluation, and critical use — areas where a Masters in Education program is particularly well-placed to intervene.

Within perceived usefulness, the lowest-rated item was job performance improvement ($M = 3.80$, $SD = 1.01$), mirroring Kumar and Raman's (2022) finding that students hold more cautious views about AI in professional contexts. For a Masters in Education cohort, these concerns are particularly salient: students are training as future educators who will navigate AI integration in their own classrooms. Program curriculum should therefore include not only practical AI skills but critical frameworks for thinking about AI's pedagogical implications.

Behavioral intention scores ($M = 4.06$) indicate genuine commitment to continued AI use. Slightly lower scores for unconditional availability usage ($M = 3.95$) and recommendation to others ($M = 3.90$) suggest contextually nuanced rather than uncritical adoption intentions — a mature disposition that reinforces the importance of fostering critical AI engagement rather than treating positive perceptions as sufficient for responsible adoption.

As a pilot study with $n = 20$ from a single cohort, these findings cannot be generalised beyond this population. The absence of demographic analysis is a further limitation, given mixed evidence regarding the moderating roles of gender and prior AI experience (Yilmaz et al., 2023; Nouraldeem, 2023). Future research should integrate a structured qualitative component — interviews or focus groups — to more systematically capture the concerns around

accuracy, tool effectiveness, and educational implications that emerged in this study.

The findings point toward three concrete areas for curriculum development within the Masters in Education program. First, given students' confidence in basic usability but uncertainty about maximising AI tools, the program should incorporate structured AI effectiveness training — including prompting strategies, output evaluation, and iterative use — rather than assuming that ease of adoption equates to effective adoption. Second, given reservations about accuracy, students would benefit from explicit instruction in AI fact-checking, source triangulation, and critical assessment of AI-generated content, skills that are directly transferable to their roles as future educators. Third, the concerns raised about AI's broader implications for education suggest that a dedicated module or seminar addressing AI ethics, academic integrity, and pedagogical implications would be both relevant and valued by this cohort. Such a module would align the program's AI integration with its core mission of preparing reflective, critically informed educators.

4. CONCLUSIONS

This pilot study provides preliminary empirical evidence of strongly positive AI perceptions among post-graduate students in an international Masters in Education program, while surfacing important nuances that have direct implications for program development. The TAM framework

demonstrated strong applicability in this context, with high intercorrelations between constructs and means significantly above conservative thresholds across all three dimensions. Informal discussion enriched these findings by revealing that positive perceptions coexist with genuine concerns about accuracy, tool effectiveness, and the future of AI in education. Post-graduate students remain an understudied population in the AI acceptance literature, and this study contributes to addressing that gap. The findings support the development of targeted AI literacy training within the Masters in Education program, with particular attention to critical and effective use rather than basic adoption. They also establish a preliminary evidence base for a larger, multi-institution follow-up study designed to examine these patterns across diverse post-graduate populations, disciplines, and cultural contexts.

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Smart education technology acceptance among Chinese postgraduate administrators in an international program: A pilot case study

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ABSTRACT

This pilot case study examines the perceptions of Chinese postgraduate educational administrators toward the integration of artificial intelligence (AI), Learning Management Systems (LMS), and Internet of Things (IoT) technologies in higher education administration. The study addresses a three-layered research gap: the near-absence of administrator-focused technology acceptance research, the lack of studies examining Chinese administrators as future institutional policy implementers, and the scarcity of research capturing practitioners who combine direct Chinese higher education experience with international study exposure. Grounded in Davis's (1989) Technology Acceptance Model (TAM), a structured bilingual questionnaire assessed perceived usefulness, ease of use, attitudes, and behavioural intentions across all three technologies. Data were collected from a complete program cohort of 21 Chinese master's students in educational administration at Rajamangala University of Technology Krungthep, Bangkok, Thailand (95.2% response rate). Analysis using a five-band Likert scale revealed strongly positive perceptions of usefulness and behavioural intentions across all three technologies. A meaningful ease-of-use gradient emerged: LMS and AI tools were rated in the agree range, while IoT setup and maintenance fell in the neutral band — the study's most critical finding, representing a stark divergence between recognised value ($M = 5.00$) and perceived operational complexity ($M = 2.88$). Informal interviews confirmed enthusiasm for all three technologies alongside uncertainty about maximising AI's potential and reservations about IoT deployment complexity. The findings carry direct implications for postgraduate program design and establish an empirical foundation for a larger multi-institution follow-up study.

Keywords: AI, LMS, IoT, higher education administration, pilot case study

1. INTRODUCTION

The convergence of AI, LMS, and IoT technologies is reshaping higher education, transforming not only teaching and learning but how institutions are administered,

resourced, and strategically governed. AI enables adaptive learning and predictive analytics; LMS platforms streamline content delivery and institutional communication; and IoT creates smart campus environments supporting real-time monitoring and resource

optimisation. Together, these technologies constitute the infrastructure of smart education — an integrated, data-driven model with significant implications for administrative practice worldwide (Badshah et al., 2023; Chen et al., 2021).

China's strategic investment in this agenda is substantial, with national policy frameworks positioning educational technology modernisation as a central priority. Yet the success of this agenda depends on the readiness and decision-making of the administrators who govern these institutions — practitioners who set priorities, allocate resources, and determine whether technological investment translates into meaningful practice. Despite this, most TAM-based technology acceptance studies in higher education have focused on students or faculty, leaving administrators as a distinct, policy-oriented population largely absent from the empirical record. This gap is deepened further when the population combines direct Chinese institutional experience with international postgraduate study — a dual perspective that is both practically grounded and cross-culturally informed.

This pilot case study addresses that gap by examining technology perceptions among a complete cohort of Chinese master's students in educational administration at a Thai international university — administrators who will return to positions of institutional influence in Chinese higher education. The study

generates preliminary evidence with direct implications for program development and establishes a foundation for a larger multi-institution follow-up investigation.

Three specific gaps constrain current understanding. First, technology acceptance research has concentrated overwhelmingly on students and faculty, leaving administrators — whose perceptions shape institutional technology policy — largely absent from the empirical record. Second, while Chinese higher education institutions are among the most active adopters of educational technology globally, Chinese administrator perspectives have received limited systematic attention through validated frameworks such as TAM. Third, Chinese administrators in international postgraduate programs represent a uniquely positioned population whose cross-cultural vantage point has not previously been examined in the technology acceptance literature. Without evidence from this population, institutions lack the insights needed to design effective administrator training, and the field lacks a foundation for comparative multi-institution research.

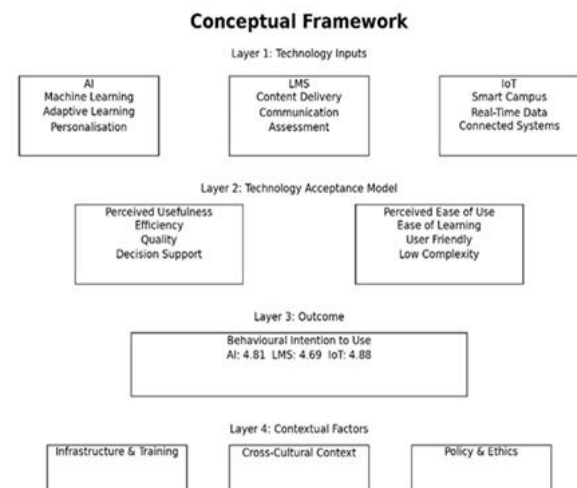
This study contributes preliminary empirical evidence on an understudied population — Chinese higher education administrators — regarding three converging technologies examined simultaneously through a single validated framework. By positioning participants as future policy implementers rather than mere technology users, it reframes technology acceptance

research as a concern with institutional reach. For international postgraduate programs, the findings offer actionable curriculum guidance. For Chinese higher education institutions, they surface perceptions directly relevant to technology integration planning. As a pilot case study, the work establishes the methodological and empirical foundation for a larger multi-institution comparative investigation.

The study is structured around three technological dimensions. AI encompasses machine learning, adaptive learning systems, and predictive analytics supporting personalised education and administrative efficiency. LMS platforms provide digital infrastructure for content delivery, communication, collaboration, assessment, and analytics. IoT integrates smart devices and sensors for real-time data collection, campus resource management, and physical-digital integration. Together, these dimensions constitute the technological architecture of smart education.

The theoretical foundation is Davis's (1989) TAM, which proposes that perceived usefulness and perceived ease of use are the primary determinants of technology acceptance and adoption intention. TAM is particularly well-suited here because it captures not only whether users value a technology but whether they believe they can use it effectively — a distinction that proves critical in interpreting the differentiated ease-of-use findings across the three technologies. Behavioural intention

serves as the primary outcome variable. The framework is moderated by infrastructure readiness, cross-cultural institutional experience, and policy environment — all



relevant to a cohort bridging Chinese and international higher education contexts (see Figure 1).

Figure 1. Conceptual framework illustrating the application of the Technology Acceptance Model (Davis, 1989) to the integration of AI, LMS, and IoT in higher education administration. Perceived Usefulness and Perceived Ease of Use jointly determine Behavioural Intention, moderated by infrastructure, cross-cultural context, and institutional policy factors.

Research Questions

1. How do Chinese postgraduate educational administrators perceive the usefulness of AI, LMS, and IoT technologies in higher education administration?
2. How do Chinese postgraduate educational administrators perceive the ease

of use of AI, LMS, and IoT technologies in higher education administration?

3. What are the behavioural intentions of Chinese postgraduate educational administrators toward adopting AI, LMS, and IoT technologies in their future institutional roles?

4. What gaps exist between technology enthusiasm and operational confidence among Chinese postgraduate educational administrators regarding AI, LMS, and IoT integration?

Literature Review

Research on AI, LMS, and IoT integration in higher education reveals a consistent pattern: strong institutional enthusiasm alongside persistent practical barriers rooted in infrastructure readiness, technical competency, and usability.

Wu (2024) identified clear regional differences in LMS priorities between Chinese and European institutions, with China emphasising centralised monitoring and digital campus integration — context directly relevant to interpreting this cohort's perceptions. Huang and Duangekanong (2022) found perceived usefulness and positive attitudes to be the primary predictors of LMS adoption intention in Sichuan, China, a pattern directly reflected in the present results.

On AI, Wang et al. (2025) found through interviews with Chinese academic leaders that AI had progressed more readily

in administrative functions than in core academic activities, with digital literacy gaps as the primary obstacle — providing important context for the enthusiasm-competence gap identified in this study. Egwurugwu and Eliphaletphebe (2024) similarly found favourable administrator attitudes toward AI alongside insufficient technical training and infrastructure concerns, echoing themes from the present interview data.

The IoT literature is particularly instructive. Saadé et al. (2023) highlighted widespread educator unpreparedness for IoT-AI convergence, advocating for substantially stronger technical competency development as a prerequisite for adoption. Madni et al. (2022) identified infrastructure readiness, ease of use, and network security as critical IoT barriers in developing country higher education — findings that directly contextualise the neutral IoT ease-of-use scores reported here. Yau and Choi (2025) reinforced the centrality of usability, finding intuitive design and preparatory guidance to be key predictors of satisfaction with smart educational technologies.

At the system level, Badshah et al. (2023) and Chen et al. (2021) underscore that successful smart education requires aligned institutional support and attention to the interoperability of AI, LMS, and IoT systems — the capabilities that postgraduate programs for educational administrators are positioned to develop. Zhang et al. (2025) advocated for improved digital literacy in AI-

assisted higher education in China, echoing the training imperatives the present findings reinforce.

2. MATERIALS AND METHODS

This study employs a quantitative descriptive design with supplementary qualitative data, positioned as a pilot case study following Yin's (2018) bounded case study approach. The case is defined as a complete, professionally homogeneous cohort in a single international postgraduate program. The methodological goal is not statistical generalisation but the generation of rich, internally consistent preliminary evidence from a theoretically significant and underexamined cohort.

Participants comprised 21 Chinese master's students enrolled in the Educational Administration program at Rajamangala University of Technology Krungthep, Bangkok, Thailand — all holding active professional backgrounds in Chinese higher education administration. All 21 cohort members were invited to participate; 20 useable responses were obtained (95.2% response rate). One questionnaire was excluded following standard data quality screening for straight-line responding. The near-complete cohort capture and shared professional profile strengthen the representativeness and interpretive value of the findings within this bounded population.

A bilingual (English-Chinese) structured questionnaire assessed perceived usefulness, ease of use, attitudes, and behavioural intentions for each technology,

alongside open-ended items eliciting experiences, barriers, and recommendations. Responses were interpreted using a five-band scale: 1.00–1.80 strongly disagree; 1.81–2.60 disagree; 2.61–3.40 neutral; 3.41–4.20 agree; 4.21–5.00 strongly agree. Overall internal consistency was acceptable (Cronbach's $\alpha = .72$); the conservative alpha likely reflects the single instrument spanning three technologies with distinct usability profiles, supporting the case for technology-specific instruments in follow-up research. Informal interviews were conducted with all participants following questionnaire completion, with recurring themes noted systematically.

Ethical approval was secured prior to data collection. All participants provided informed consent and were assured of confidentiality and voluntary participation.

3. RESULTS AND DISCUSSION

The following section shows the quantitative and qualitative results.

Table 1 Artificial Intelligence — Perceived Usefulness, Ease of Use, Attitude, and Behavioural Intention

Statement	Mean	SD	Band
Using AI will improve the efficiency of administrative tasks	4.62	0.50	Strongly Agree
Integrating these technologies	4.69	0.46	Strongly Agree

will improve overall quality of HE administration			
I intend to use AI tools in my future administrative work	4.80	0.40	
AI tools for administration are easy to learn and operate	4.06	0.57	Strongly Agree
I feel confident in my ability to use these technologies effectively	3.81	0.54	Strongly Agree
I have a positive attitude toward using AI in educational administration	4.79	0.39	Strongly Agree
I am enthusiastic about adopting new technologies in higher education	4.81	0.40	Strongly Agree
I will support the integration of AI, LMS, and IoT into	4.86	0.33	Strongly Agree

university administration			

Table 2 Learning Management Systems — Perceived Usefulness, Ease of Use, Attitude, and Behavioural Intention

Statement	Mean	SD	Band
LMS platforms make it easier to manage and deliver academic content	4.69	0.48	Strongly Agree
LMS platforms are user-friendly for both administrators and educators	4.38	0.50	Strongly Agree
I believe LMS platforms will remain important for future educational management	4.75	0.45	Strongly Agree
I plan to encourage others to use LMS platforms in their work	4.69	0.47	Strongly Agree

Table 3 Internet of Things — Perceived Usefulness, Ease of Use, Attitude, and Behavioural Intention

Statement	Mean	SD	Band

IoT technologies enhance the management of physical and digital resources on campus	4.62	0.50	Strongly Agree
IoT devices in education are simple to set up and maintain	2.88	0.50	Strongly Agree
IoT technology is valuable for creating smart and efficient campuses	5.00	0.00	Strongly Agree
I am willing to learn more about IoT applications in higher education	4.88	0.38	Strongly Agree

Across all three technologies, perceived usefulness and behavioural intention items scored consistently in the strongly agree band ($M = 4.62\text{--}5.00$). The IoT smart campus value item ($M = 5.00$, $SD = 0.00$) represents the strongest consensus in the dataset, with zero variance indicating unanimous agreement. Standard deviations were consistently low throughout, reflecting cohort-level consensus.

Ease of use produced the study's most analytically important pattern: a clear

technology-specific gradient of LMS ($M = 4.38$) > AI ($M = 4.06$) > IoT ($M = 2.88$). IoT setup and maintenance was the only item in the study to fall below the agree threshold and the single most notable quantitative finding. Usage confidence ($M = 3.81$) also fell in the agree range, indicating a gap between enthusiasm and operational self-assurance.

Three consistent themes emerged. First, participants expressed strong enthusiasm for AI and LMS, describing both as already familiar in Chinese institutional contexts. Second, participants acknowledged using AI tools regularly but expressed uncertainty about whether they were exploiting their full capability — a nuanced finding that parallels the agree-range confidence score and identifies a gap between surface adoption and effective strategic use. Third, IoT generated the most ambivalence: participants unanimously recognised its smart campus potential (reflected in $M = 5.00$) but cited installation complexity, maintenance demands, and workload implications as sources of operational hesitation. Data privacy was mentioned but generally considered manageable through institutional policy.

Strongly agree ratings for usefulness and behavioural intentions across all three technologies align with Wu (2024) and Huang and Duangekanong (2022), who identified perceived usefulness and positive attitudes as primary adoption drivers in Chinese higher education. More significantly, the high behavioural intention scores ($M = 4.81\text{--}4.88$)

indicate that participants are not passive technology users but active future advocates — administrators oriented toward implementation and institutional leadership. For institutions advancing smart education in China, this cohort represents a motivated implementation asset. The challenge is not motivational; it is competency-focused.

The differentiated ease-of-use profile is the study's most analytically significant finding. The gradient — LMS ($M = 4.38$) > AI ($M = 4.06$) > IoT ($M = 2.88$) — mirrors the maturity trajectory and institutional embeddedness of these technologies in Chinese higher education. LMS platforms are well-established infrastructure; AI is increasingly accessible through familiar interfaces; IoT remains technically complex and infrastructure-dependent. The neutral IoT score does not represent opposition but ambivalence — participants unanimously affirm IoT's value while expressing uncertainty about deployment. This resonates directly with Saadé et al. (2023) and Madni et al. (2022), who identified IoT complexity and maintenance burden as primary educational adoption barriers. The implication for institutions is precise: the goal is not to build IoT support but to convert existing enthusiasm into operational confidence through targeted hands-on training.

The gap between high enthusiasm ($M = 4.81$) and moderate usage confidence ($M = 3.81$) is of particular significance for program design. Interview data confirmed participants

felt comfortable with AI at a surface level but uncertain about strategic effectiveness — distinguishing adoption from proficiency in ways that enthusiasm scores alone do not capture. This extends Wang et al.'s (2025) finding that AI integration in Chinese universities has progressed more readily at the administrative surface than in deeper functions, and echoes Egwurugwu and Eliphaletphebe (2024). For a Masters in Educational Administration program, the implication is clear: AI literacy training must extend beyond tool familiarity to encompass effective prompting, critical output evaluation, and strategic application to complex administrative challenges.

The consistently low standard deviations throughout the dataset — including zero variance on the IoT smart campus item — indicate that findings reflect coherent, shared perceptions grounded in common professional experience rather than idiosyncratic individual responses. This internal coherence, combined with near-complete cohort capture, strengthens interpretive confidence within this bounded case.

Acknowledged limitations include the $n = 21$ single-cohort design, which prevents generalisation beyond this population; the absence of demographic sub-analysis; informal rather than formally coded qualitative data; and a conservative Cronbach's α (.72) that supports the case for technology-specific instruments in follow-up research.

Three priority areas emerge. First, programs should incorporate structured AI effectiveness training extending beyond tool introduction to cover advanced prompting, critical output evaluation, and strategic administrative application — addressing the competency gap directly. Second, the neutral IoT ease-of-use finding indicates that conceptual awareness is insufficient; professional development must provide hands-on experience with IoT deployment, maintenance, and troubleshooting to convert strategic conviction into operational capability. Third, the high behavioural intentions across all technologies represent a motivation asset programs should leverage through structured exposure to integrated AI-LMS-IoT environments, comparative institutional case analysis, and technology leadership projects during the period of international study.

4. CONCLUSIONS

This pilot case study provides preliminary evidence of strongly positive and internally coherent perceptions among Chinese postgraduate educational administrators toward AI, LMS, and IoT in higher education. Usefulness and behavioural intention scores fell consistently in the strongly agree band across all three technologies. The ease-of-use gradient — LMS and AI in the agree range, IoT in the neutral band — identifies a meaningful and actionable differentiation reflecting the distinct maturity and infrastructural profiles of these technologies in Chinese educational

environments. The gap between enthusiasm and operational confidence, confirmed by interview data across both AI and IoT, points toward specific program priorities centred on depth of AI literacy and practical IoT competency.

The cross-cultural, professionally experienced profile of this cohort — practitioners combining direct Chinese institutional experience with international postgraduate study — constitutes the study's primary contribution and its strongest rationale for follow-up research. These findings address a demonstrable gap in the technology acceptance literature and establish an empirical foundation for a larger multi-institution comparative study that would extend this investigation across institutions and administrative demographics, building a richer account of how educational administrators in international contexts perceive and prepare to implement the technologies reshaping higher education globally.

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Enhancing Comprehension and Engagement through AI and Multimodal Language Support in an English-Medium Education Technology Course

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ABSTRACT

This study examined the effectiveness of integrated language support strategies in an English-medium Education Technology course delivered to 16 international master's students at a Thai public university. Employing a mixed-methods design, data were collected via a 28-item, five-point Likert scale questionnaire (Cronbach's $\alpha = .90$) and supplementary open-ended feedback. The redesigned 45-hour course incorporated advance vocabulary lists with translations, visual aids, simplified language, paced delivery with comprehension checks, AI-powered translation tools, and structured in-class assignments. One-sample t-tests ($\mu_0 = 3.40$) confirmed that mean scores across all 28 items were significantly above the criterion threshold (all $p < .05$). Section-level means were: Language Barriers ($M = 4.40$, $SD = 0.70$), Motivation to Use English ($M = 4.53$, $SD = 0.66$), and Satisfaction with Course Design ($M = 4.31$, $SD = 0.78$). A significant positive correlation was found between motivation and satisfaction ($r = .60$, $p = .015$), while language barrier support showed a moderate but non-significant correlation with satisfaction ($r = .31$, $p = .243$). Thematic analysis of qualitative responses reinforced the quantitative findings, highlighting students' appreciation for structured vocabulary support and the course's relevance to their academic and professional goals. Persistent challenges with specialised terminology were identified as an area for further development. These findings provide evidence for embedding systematic language support in content-based instruction for multilingual learners in higher education.

Keywords: English-medium instruction, language support strategies, international students, Education Technology, mixed-methods research

1. INTRODUCTION

International students enrolled in English-medium academic programmes frequently encounter compounded challenges when learning complex subject matter in a language that is not their mother tongue. These difficulties are especially acute in discipline-specific fields such as Education Technology, where mastery of both advanced content and specialised

vocabulary is essential for academic performance. The present study focuses on a redesigned master-level Education Technology course taught in English to a cohort of Chinese international students at a Thai public university, with the explicit aim of addressing language-related barriers to learning.

The course was redesigned to incorporate a set of targeted pedagogical

interventions: (1) advance vocabulary lists with examples and translations provided prior to each lesson; (2) visual aids such as diagrams, charts, and infographics embedded throughout instruction; (3) simplified and scaffolded language with explicit definition of technical terms; (4) a reduced instructional pace with regular pauses and comprehension-checking questions; (5) the integration of QR codes linking to supplementary online resources; (6) encouragement of AI-powered translation tools for processing unfamiliar terminology; and (7) structured in-class assignments that allowed time for translation and peer collaboration on cognitively demanding tasks.

The broader context for this study is the rapid global growth in English-taught degree programmes (ETPs). Between 2021 and 2024, the number of on-campus ETPs worldwide increased by 22%, driven by higher education internationalisation strategies and, in part, by rising visa refusal rates in traditional Anglophone destinations such as Australia, Canada, the United Kingdom, and the United States [1]. This shift has placed significant responsibility on instructors in non-Anglophone institutions to design courses that are linguistically accessible without compromising disciplinary rigour.

The goal of this research was to evaluate the effectiveness of these

instructional strategies in improving students' comprehension of course material, motivation to engage with English, and overall satisfaction with the course design.

1.1 Statement of the Problem

International students often face difficulties understanding course content delivered in English, particularly in specialised fields where technical vocabulary and advanced concepts are central to the curriculum. These challenges can adversely affect engagement, motivation, and academic outcomes [2], [3]. Although various instructional strategies have been proposed to support non-native English speakers in higher education, empirical studies focusing specifically on how systematic pedagogical modifications enhance comprehension in discipline-specific EMI courses remain limited. This research aims to address this gap by examining the effectiveness of an integrated suite of language support strategies within a master-level Education Technology course.

1.2 Significance of the Research

This study contributes to the evidence base for content-based language support in higher education in three ways. First, it provides quantitative and qualitative evidence of strategy effectiveness in an under-researched context: an EMI course at a non-Anglophone Asian university serving Chinese postgraduate students. Second, it demonstrates the feasibility and student acceptance of AI-powered translation tools as a legitimate pedagogical resource in EMI

settings, contributing to emerging scholarship on technology-mediated language support [4], [5]. Third, the study offers practical, replicable guidance for instructors and curriculum designers seeking to create more inclusive and linguistically supportive learning environments for international learners.

1.3 Literature review

International students in English-medium settings face a well-documented array of linguistic and cultural challenges. Language and cultural factors are deeply intertwined, each shaping the other, and students must adapt to unfamiliar learning and communication styles while simultaneously mastering new disciplinary content [6]. Among the most consistently reported difficulties are challenges in classroom comprehension, academic writing, and oral participation.

Research on Asian students studying in Australia has shown that many continue to experience difficulties despite years of English instruction, stemming largely from prior educational experiences that emphasised grammar and reading in teacher-centred classrooms, with limited attention to conversational competence [7]. Similarly, Zhang and Mi [8] found that Chinese students at Australian universities reported persistent difficulties with listening and speaking, particularly during the first two years of study, while reading was generally manageable and

writing difficulties persisted across disciplines regardless of study duration.

At the institutional level, Aizawa et al. [9] demonstrated that TOEIC-measured English proficiency was a significant predictor of EMI difficulty among Japanese undergraduates, yet interview data revealed that factors beyond language proficiency—including prior content knowledge, motivation, and the classroom environment—also shaped students' perceived ease of study. Kamaşak et al. [10] similarly found that writing and speaking presented the greatest difficulty for EMI students in Turkey, with reported issues varying by academic discipline, native language, and previous EMI experience.

Vocabulary support has been identified as a critical intervention for EMI learners. Demir and Ayten [11] found that limited vocabulary was the most common barrier for international students in Turkish-medium content courses, with instructors rating students' vocabulary difficulties as more severe than students themselves recognised—a finding that underscores the importance of proactive vocabulary scaffolding. With regard to instructional pace, Yurtbaşı [12] argued that reducing speech speed and using strategic pauses demonstrably improves clarity and aids cognitive processing and information retention for non-native English speakers.

The role of visual aids in supporting English language learners has also received

empirical attention. Yang [13] found that combining concrete graphics with animation produced the highest achievement outcomes for non-native English-speaking students in computer-based instruction, significantly outperforming text-only, static graphic, or abstract graphic conditions. These findings suggest important implications for multimodal course design.

Finally, the integration of machine translation (MT) and AI-powered translation tools in academic settings has become an increasingly relevant area of inquiry. Sun and Yang [14] found that translation-friendly writing strategies using MT tools improved the quality of EFL students' academic abstracts, though students raised ethical concerns about MT use in academic writing. Yang et al. [5] reported that most surveyed students viewed translation software as a valuable tool for language learning and communication, though cautioned that it should be used alongside—not in place of—authentic language input and independent learning. These findings support a balanced, pedagogically guided approach to AI translation tool use in EMI contexts.

2. MATERIALS AND METHODS

2.1 Research Design

This study employed a mixed-methods design, integrating quantitative data from a Likert scale questionnaire with qualitative data from open-ended written feedback and instructor-conducted interviews. This approach enabled both statistical assessment of strategy

effectiveness and interpretive exploration of students' subjective experiences and perceptions [15].

2.2 Participants and Context

Participants were 16 Chinese international students (N = 16) enrolled in a 45-hour Education Technology course as part of a master's degree programme at a Thai public university. Students exhibited varying levels of English proficiency; all had completed prior English language coursework but were non-native English speakers for whom English-medium instruction was an additional cognitive demand. Participation was voluntary and no incentives were offered. The small sample size is a recognised limitation of this study, discussed in Section 5.

2.3 Course Design and Interventions

The course was redesigned from a standard content-delivery format to incorporate seven categories of language support intervention: (1) advance vocabulary lists with L1 translations (Chinese) and contextual examples distributed prior to each lesson; (2) embedded visual aids including diagrams, charts, and infographics illustrating key concepts; (3) simplified and scaffolded instructional language with explicit definition and repeated use of technical terminology; (4) reduced instructional pace with strategic pauses; (5) comprehension-checking questions distributed throughout each lesson to provide formative feedback opportunities; (6) QR codes linking to supplementary digital

resources; and (7) structured in-class assignments for cognitively demanding tasks, providing time for AI-assisted translation and peer collaboration. Students were explicitly encouraged to use AI translation tools (e.g., Google Translate, DeepL) as comprehension aids, with guidance on appropriate academic use.

2.4 Data Collection Instruments

Data were collected through three instruments. The primary instrument was a 28-item, five-point Likert scale questionnaire (1 = Strongly Disagree to 5 = Strongly Agree) administered at the end of the course. Items were grouped into three theoretically derived sections: Language Barriers and Support (LB, 9 items), Motivation to Use English (MU, 10 items), and Satisfaction with Course Design (S, 9 items). Internal consistency reliability was assessed using Cronbach's alpha, yielding $\alpha = .76$ for LB, $\alpha = .86$ for MU, $\alpha = .91$ for S, and $\alpha = .90$ overall, indicating high reliability across all sections [16]. Students were also invited to provide open-ended written feedback; they were permitted to use AI translation assistance when writing responses to ensure language barriers did not impede expression. Additionally, follow-up informal interviews were conducted to deepen interpretation of questionnaire trends.

2.5 Data Analysis

Quantitative data were analysed using descriptive statistics (means and standard deviations) and one-sample t-tests conducted against a criterion mean of $\mu_0 =$

3.40, representing the midpoint between neutral and agreement on the 5-point scale. This criterion was adopted to establish whether agreement was meaningfully above neutral, rather than simply above the scale midpoint. Inter-section Pearson correlations were also computed to examine relationships among the three constructs. Qualitative data from open-ended responses and interviews were analysed thematically following Braun and Clarke's framework, with themes identified independently and then consolidated through discussion to ensure credibility.

3. RESULTS AND DISCUSSION

3.1 Reliability

Table 1 presents reliability coefficients and section-level descriptive statistics. All three sections demonstrated acceptable to excellent internal consistency (LB: $\alpha = .76$; MU: $\alpha = .86$; S: $\alpha = .91$; Overall: $\alpha = .90$). Section-level mean scores were consistently high: Language Barriers ($M = 4.40$, $SD = 0.70$), Motivation ($M = 4.53$, $SD = 0.66$), and Satisfaction ($M = 4.31$, $SD = 0.78$). One-sample t-tests comparing each section mean against the criterion of $\mu_0 = 3.40$ were all statistically significant (LB: $t = 17.03$, $p < .001$; MU: $t = 21.59$, $p < .001$; S: $t = 13.81$, $p < .001$), confirming that student agreement was meaningfully above the neutral-to-agreement threshold across all three domains.

3.2 Item-Level Results

Table 2 presents item-level means, standard deviations, percentage of

agree/strongly agree responses, and one-sample t-test results for all 28 items. All items achieved statistical significance (all $p < .05$), confirming that agreement was above

the criterion threshold across the full questionnaire. Several patterns warrant specific discussion.

Table 1. Section-level descriptive statistics and reliability coefficients (N = 16)

Section	n Items	M (section)	SD	Cronbach's α
Language Barriers (LB)	9	4.40	0.70	.76
Motivation to Use English (MU)	10	4.53	0.66	.86
Satisfaction with Course Design (S)	9	4.31	0.78	.91
Overall	28	4.41	0.72	.90

Table 2. Item-level questionnaire results: descriptive statistics and one-sample t-tests ($\mu_0 = 3.40$, N = 16)

Item	Statement	% Agree/ Strongly Agree	M	SD	p
Section 1: Language Barriers (LB) — Cronbach's $\alpha = .76$					
LB1	The course vocabulary list provided in advance helped me understand the lessons better.	93.8%	4.69	0.60	< .001
LB2	The examples and translations of key vocabulary were helpful in understanding the course material.	100.0%	4.69	0.48	< .001
LB3	I have difficulty understanding specialized terms and concepts presented in English.	68.8%	4.00	0.97	.025
LB4	Using AI-powered translation tools helped me understand difficult terms and concepts.	93.8%	4.31	0.60	< .001
LB5	I felt confident in my understanding of the course material after receiving translations for key terms.	75.0%	4.19	0.83	.002
LB6	The simplified language used in the course helped me overcome language barriers.	100.0%	4.38	0.50	< .001

Item	Statement	% Agree/ Strongly Agree	M	SD	p
LB7	The use of visual aids (such as diagrams and charts) helped me better understand complex terms in English.	93.8%	4.56	0.63	< .001
LB8	The pace of the lessons allowed me enough time to understand and process the English content.	87.5%	4.38	0.72	< .001
LB9	The checking questions used throughout the lessons helped clarify any misunderstandings related to language.	87.5%	4.38	0.72	< .001
Section 2: Motivation to Use English (MU) — Cronbach's α = .86					
MU1	I am motivated to improve my English because I need it for my academic studies.	100.0%	4.62	0.50	< .001
MU2	I feel more motivated to learn English as a result of taking this course.	87.5%	4.31	0.70	< .001
MU3	I believe that improving my English skills will help me achieve my academic and professional goals.	87.5%	4.62	0.72	< .001
MU4	I am confident in my ability to use English for academic purposes, such as reading, writing, and presenting.	81.2%	4.19	0.75	< .001
MU5	I am more interested in improving my English because of the specific vocabulary and language used in this course.	93.8%	4.50	0.63	< .001
MU6	I feel that learning English through this course is a valuable skill that will benefit me in my future career.	87.5%	4.50	0.73	< .001
MU7	I am motivated to learn English because it helps me better understand the course content in Education Technology.	93.8%	4.62	0.62	< .001
MU8	The language support provided in this course (e.g., vocabulary lists, translations) made me feel	93.8%	4.75	0.58	< .001

Item	Statement	% Agree/ Strongly Agree	M	SD	p
	more motivated to continue improving my English.				
MU9	I feel that my motivation to improve my English is influenced by how useful English is for my academic and professional success.	93.8%	4.50	0.63	< .001
MU10	I would be more likely to study English in the future if the content was connected to my academic and career interests, such as Education Technology.	87.5%	4.69	0.70	< .001
Section 3: Satisfaction with Course Design (S) — Cronbach's $\alpha = .91$					
S1	The visual aids (e.g., diagrams, charts, and images) helped me understand the course content more effectively.	81.2%	4.31	0.79	< .001
S2	The slower pace of the lessons allowed me to process and understand the material more thoroughly.	87.5%	4.38	0.72	< .001
S3	The checking questions used throughout the lessons helped me gauge my understanding of the material.	81.2%	4.31	0.79	< .001
S4	The in-class assignments allowed me enough time to complete tasks with the support of translation tools or peers.	93.8%	4.44	0.63	< .001
S5	The overall course design made it easier for me to understand complex concepts in Education Technology.	81.2%	4.25	0.93	.002
S6	The course materials (e.g., readings, slides) were clear and easy to understand, even though the course was in English.	87.5%	4.38	0.72	< .001
S7	I was able to follow the lessons easily due to the regular pauses and checking questions.	81.2%	4.19	0.91	.004

Item	Statement	% Agree/ Strongly Agree	M	SD	p
S8	The support strategies (e.g., vocabulary lists, translations, visuals) improved my overall learning experience in this course.	75.0%	4.12	0.96	.009
S9	I felt more engaged in the course because the language support strategies were consistently applied.	87.5%	4.38	0.72	< .001

Note. M = mean; SD = standard deviation; p-values from one-sample t-tests against criterion $\mu_0 = 3.40$.

Items marked with † indicate comparatively lower agreement (< 80%). Cronbach's α reported per section in Table 1.

3.3 Language Barrier Support

Within the Language Barriers section, the highest-scoring items were LB2 (M = 4.69, SD = 0.48; 100% agree/strongly agree) regarding vocabulary examples and translations, and LB1 (M = 4.69, SD = 0.60; 93.8%) regarding advance vocabulary lists. These results indicate that pre-lesson vocabulary scaffolding was the most universally valued intervention, consistent with Demir and Ayten's [11] finding that vocabulary limitations constitute the primary barrier for international students in content courses. Visual aids (LB7: M = 4.56) and simplified language (LB6: M = 4.38, 100%) also received strong endorsement.

Notably, LB3 ("I have difficulty understanding specialised terms and concepts presented in English") produced the lowest mean (M = 4.00, SD = 0.97) and the

lowest percentage of agree/strongly agree responses (68.8%), though it remained statistically significant (p = .025). While this item is worded to measure the presence of difficulty rather than the effectiveness of a support strategy, the comparatively high standard deviation (SD = 0.97) indicates meaningful variation in students' experiences of terminology difficulty. This suggests that, despite the array of language support measures, a subset of students continued to find specialised academic vocabulary challenging—a finding consistent with Kamaşak et al. [10] and Aizawa et al. [9], who noted that linguistic challenges in EMI persist even among motivated and proficiency-stratified learners.

3.4 Motivation to Use English

The Motivation section yielded the highest section mean (M = 4.53, SD = 0.66).

The top-scoring item was MU8 ($M = 4.75$, $SD = 0.58$; 93.8%), indicating that the language support provided in the course made students feel more motivated to continue improving their English. Items MU1 ($M = 4.62$), MU3 ($M = 4.62$), MU7 ($M = 4.62$), and MU10 ($M = 4.69$) all scored above 4.60, reflecting strong instrumental and integrative motivation linked to students' academic and career goals. These findings are consistent with research demonstrating that EMI motivation is shaped not only by language proficiency, but by perceptions of content relevance and environmental support [9]. The practical relevance of Education Technology to students' professional aspirations appears to have functioned as a significant motivational driver.

3.5 Satisfaction with Course Design

Satisfaction items demonstrated slightly greater variability than the other two sections ($\alpha = .91$), with S8 producing the lowest mean across the entire questionnaire ($M = 4.12$, $SD = 0.96$; 75.0%; $p = .009$). S8 assessed the overall effectiveness of the support strategies for learning experience improvement, and its higher standard deviation suggests divergent perceptions: while three-quarters of students reported that strategies improved their experience, approximately one in four did not strongly endorse this. Similarly, S7 ($M = 4.19$, $SD = 0.91$) and S5 ($M = 4.25$, $SD = 0.93$) also showed comparatively higher variability. These items relate to ease of lesson-

following and overall comprehension of complex concepts, respectively, suggesting that for some students, challenges remained in processing lesson flow even with the support structures in place. These patterns likely reflect the heterogeneity in students' prior English proficiency, a factor consistently identified in the EMI literature as a moderator of instructional strategy effectiveness [9], [10].

3.6 Inter-Section Correlations

Table 3 presents Pearson correlations among section composite scores. A significant positive correlation was observed between Motivation and Satisfaction ($r = .60$, $p = .015$), indicating that students who reported higher motivation to use English also tended to report greater satisfaction with the course design. This relationship is theoretically consistent: students who are instrumentally motivated to improve their English are more likely to perceive and value the scaffolding structures that support that goal. By contrast, Language Barrier support was not significantly correlated with either Motivation ($r = .04$, $p = .877$) or Satisfaction ($r = .31$, $p = .243$), suggesting that perceived difficulty with specialised vocabulary operates as a somewhat independent construct from motivational orientation and course satisfaction in this sample.

Table 3. Pearson inter-section correlations (N = 16)

Section	LB	MU	S
Language Barriers (LB)	—		

Section	LB	MU	S
Motivation (MU)	.04	—	
Satisfaction (S)	.31	.60*	—

Note. * $p < .05$. LB = Language Barriers; MU = Motivation to Use English; S = Satisfaction with Course Design.

3.7 Qualitative Findings

Thematic analysis of open-ended feedback and interviews yielded three overarching themes. The first theme, structured vocabulary scaffolding as cognitive preparation, captured students' frequent descriptions of the advance vocabulary lists as a form of mental preparation that allowed them to "prime" their understanding before encountering terms in context. Several students described a sense of reduced cognitive load during lessons because key terms were already partially familiar. The second theme, content relevance as motivational anchor, reflected the observation that the practical applicability of Education Technology content to students' postgraduate studies and professional aspirations was a principal driver of motivation to engage with English. Multiple students reported that this course prompted a shift in attitude toward English learning—from obligation to perceived utility—consistent with the strong MU section scores and the significant MU–S correlation. The third theme, residual difficulties with specialised academic register, acknowledged that despite the breadth of support, a subset of students continued to find certain

technical and academic language constructions challenging, particularly in assignments requiring extended written responses. These qualitative patterns corroborate the quantitative findings, particularly the relatively lower means on LB3 and S8, and provide important context for interpreting the inter-section correlation structure.

4. CONCLUSIONS

This study provides evidence that a systematically designed suite of language support strategies can significantly enhance comprehension, motivation, and satisfaction among Chinese international students in an English-medium Education Technology course. All 28 questionnaire items yielded means significantly above the criterion threshold ($\mu_0 = 3.40$), and section-level reliabilities were acceptable to excellent. The significant correlation between motivation and satisfaction ($r = .60$) suggests that language support strategies operate, in part, through the mechanism of motivational engagement: when students feel more capable and less linguistically excluded, they also derive greater satisfaction from the learning experience.

Several practical implications follow from these findings. First, advance vocabulary scaffolding with L1 translations should be considered a baseline provision in EMI courses serving non-Anglophone learners, given its near-universal endorsement. Second, the integration of AI translation tools, when accompanied by pedagogical

guidance, appears to serve as a legitimate and valued comprehension aid rather than a shortcut that undermines learning—consistent with Yang et al. [5] and Sun and Yang [14]. Third, the persistent terminology challenges reported by a subset of students (LB3; S8) suggest that vocabulary support alone is insufficient for academic register acquisition; supplementary targeted instruction in disciplinary discourse patterns may be warranted for advanced courses.

This study has several limitations that should be acknowledged. The sample was small (N = 16) and homogeneous (all Chinese students at a single institution), which limits generalisability. The absence of a control group prevents causal attribution of outcomes to specific interventions. The post-course administration of the questionnaire introduces social desirability bias. Future research should employ larger and more diverse samples, longitudinal designs to assess sustained language development, and if feasible, comparative conditions to isolate the relative contribution of individual support strategies. Replication across different disciplinary contexts and with students of varied L1 backgrounds would substantially strengthen the evidence base for these findings.

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Soft skills in the era of artificial intelligence: an investigation of Thai undergraduate student perceptions

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ABSTRACT

As artificial intelligence continues to reshape labour market demands, higher education institutions face growing pressure to equip graduates with competencies that extend beyond technical proficiency. Soft skills such as critical thinking, communication, adaptability, emotional intelligence, and ethical reasoning are increasingly recognised as essential for effective participation in AI-integrated workplaces, yet questions remain about whether university curricula adequately develop these capabilities. This study employed a quantitative design to explore the perceptions of 47 Thai undergraduate science students regarding the importance, development, and institutional support of soft skills in the context of AI-driven career futures. Data were collected via a 30-item Likert-scale questionnaire across six thematic variables. Descriptive statistical analysis was used to analyse the data. Findings indicate that students strongly recognise the importance of soft skills in AI-augmented workplaces but report moderate self-perceived preparedness, particularly in critical thinking. Students identified a meaningful gap between university curricula and industry expectations, with the greatest perceived need centring on access to practical, work-integrated learning experiences. Recommendations favoured pedagogical reform emphasising critical thinking, mandatory internships, and dedicated instruction in ethical decision-making for AI-enhanced environments. These findings have implications for curriculum design, institutional policy, and national workforce development strategies in Thailand and comparable emerging economies navigating the challenges of the Fourth Industrial Revolution.

Keywords: soft skills; artificial intelligence; Thai higher education; undergraduate students; 21st century skills; human-AI collaboration; work-integrated learning; employability; Fourth Industrial Revolution; curriculum

1. INTRODUCTION

As artificial intelligence (AI) technologies continue to evolve and become embedded in nearly every aspect of work and life, the competencies required of the future workforce are shifting dramatically. While technical and digital literacy are essential, employers are placing growing emphasis on soft skills such as communication, critical thinking, emotional

intelligence, collaboration, adaptability, and ethical reasoning. These human-centric skills remain crucial in contexts where AI cannot yet replicate complex emotional judgments, nuanced human interaction, or ethical decision-making. Thai higher education institutions, like those around the world, are grappling with how best to equip students for a world where human-AI collaboration is the norm. While courses in digital literacy, programming, and AI applications are

expanding, questions remain about whether current educational frameworks place enough emphasis on developing soft skills in parallel. This study is situated in this intersection—between technological advancement and human development—and seeks to understand how Thai undergraduate students perceive the role and value of soft skills in an increasingly AI-driven economy.

Research Objectives

1. To explore Thai undergraduate students' perceptions of the importance of soft skills in the context of AI integration in the workplace.
2. To examine the degree to which students believe soft skills are essential for employability and success in future AI-shaped careers.
3. To assess students' self-perceived preparedness in specific soft skill areas, including communication, teamwork, adaptability, critical thinking, and emotional intelligence.
4. To evaluate the extent to which students believe their academic programs adequately support the development of these soft skills.
5. To explore students' suggestions on how higher education institutions in Thailand could improve their approach to teaching soft skills, particularly in ways that integrate

human capabilities with technical competencies required in AI-driven professions.

Significance of the Study

The significance of this study lies in its contribution to understanding the evolving role of education in preparing students for a future workforce increasingly shaped by automation and AI. While digital transformation is a prominent focus in higher education policy and curriculum development, there is a risk of underestimating the critical role that soft skills play in ensuring that graduates can successfully integrate into, and adapt within, future workplaces. This research provides empirical evidence from students themselves, offering insights into how they perceive their readiness to face a hybrid future where humans and intelligent systems work side by side.

For educators and curriculum designers, this research offers practical implications by highlighting which soft skills students value most and where they feel current academic programs fall short. By understanding students' lived experiences and expectations, universities can design courses and extracurricular opportunities that not only impart knowledge but also cultivate emotional intelligence, collaboration, creativity, and resilience. Additionally, the findings can inform national policy initiatives aimed at aligning academic outcomes with labour market needs, ensuring that Thai

graduates remain competitive in a rapidly globalizing and technologizing world. The study also underscores the urgency of embedding ethical and emotional dimensions into education to complement technical proficiency and foster responsible AI-human collaboration.

Theoretical and Conceptual Framework

This study is grounded in two complementary theoretical perspectives: the 21st Century Skills Framework and Human Capital Theory, supplemented by insights from sociotechnical systems theory.

The 21st Century Skills Framework, advanced by organizations such as the Partnership for 21st Century Learning, identifies four core competency domains—critical thinking, communication, collaboration, and creativity—as foundational for participation in modern knowledge economies [1]. This framework has been widely adopted in educational policy discussions globally and provides a lens through which students' perceptions of skill importance can be interpreted.

Human Capital Theory, originally articulated by Becker [2] and later extended by scholars including Schultz [3], holds that investment in education and skills development enhances individual productivity and economic returns. In the context of AI integration, this theory supports the argument that soft skills represent a form of non-automatable human capital that retains—and indeed increases—its economic

value as routine cognitive tasks are increasingly delegated to machines [4]. Acemoglu and Restrepo [5] extended this framing by demonstrating that automation does not uniformly displace labour but rather reshapes the task composition of jobs, elevating the relative importance of interpersonal, adaptive, and judgment-based competencies.

Sociotechnical systems theory, developed by Trist and Bamforth [6] and later elaborated by Pasmore [7], argues that effective workplace functioning requires the joint optimization of social and technical subsystems. Applied to AI-integrated environments, this perspective suggests that human workers must develop not only digital literacy but also the relational and adaptive skills necessary to collaborate effectively with intelligent systems. This theoretical lens informs the study's attention to the human dimensions of AI-human collaboration, and the gaps students perceive between their education and industry expectations.

Conceptually, this study frames soft skills as a dynamic and socially embedded set of competencies that are shaped by, and responsive to, technological change. Rather than treating soft skills as static attributes, the framework recognizes them as learnable, context-dependent capabilities that higher education institutions have both the opportunity and the responsibility to cultivate [8]. Figure 1 illustrates the conceptual relationship between AI-driven labour market transformation, soft skills

development, and educational preparedness that guides this investigation.

Literature Review

As economies transition toward knowledge-based models, there is growing emphasis on integrating information and communication technologies and cultivating a highly skilled labour force. Toma and Hudea [9] investigated Generation Z students' perceptions of the abilities and competencies necessary in the era of artificial intelligence, recognizing that unskilled labour is becoming increasingly obsolete. In their study of Romanian undergraduates, they found that students prioritized cognitive, psychomotor, and sensorial abilities, as well as general knowledge, business acumen, and technical competencies. The study highlighted the need to adapt curricula to match evolving digital requirements.

In a related study, Hasan, Nasreen, and Rasul [10] examined the role of AI-integrated learning environments in fostering essential 21st-century skills such as collaboration, communication, critical thinking, and creativity. The research, which employed a structured survey and involved students from public universities in Pakistan, found AI to be a significant contributor to the development of most soft skills—though its impact on creativity was not statistically significant. The findings suggest that AI should be integrated alongside pedagogical strategies that promote independent thinking.

Colón-Aguirre and Bright [11] explored student perceptions of AI's influence on future employment prospects through phenomenological interviews with undergraduate students. Participants acknowledged the inevitability of AI in their professional futures and expressed interest in learning how to use such tools effectively. Despite their optimism, students did not view AI as capable of replacing core human attributes such as emotional understanding and the ability to detect misinformation. The researchers emphasized the role of academic institutions in equipping students to engage meaningfully with AI tools.

The importance of soft skills continues to be a focal point in employability discussions. Succi and Canovi [12] compared perceptions of students and employers across various European countries, finding that employers placed more importance on soft skills than students did. The study revealed a clear misalignment between the priorities of higher education institutions and the expectations of the labour market. It called for stronger collaboration between academic and corporate sectors to better guide students in developing essential non-technical skills.

In China, Luo and Li [13] investigated the use of microlearning as a method for enhancing soft skills development across disciplines. Their study demonstrated that tailored microlearning modules led to measurable improvements in leadership, communication, and emotional intelligence

among students, though outcomes varied by academic field. The authors concluded that microlearning, when customized to disciplinary contexts, can bridge the gap between theoretical knowledge and professional requirements.

Zogopoulos and Raptis [14] studied student perceptions of employability skills in the context of the Fourth Industrial Revolution. Their findings indicated that students placed greater importance on practical hard skills, such as equipment handling, than on programming or mathematics. Soft skills, including critical thinking and active listening, were also valued, although students expressed concerns about the long-term sufficiency of their degree programs in preparing them for future job markets.

Mkhize and Reddy [15] addressed the disconnect between student self-perception and employer expectations regarding work readiness in South Africa. While students rated their future employability positively, employers highlighted significant deficiencies in soft skills like critical thinking and communication. The study emphasized the importance of work-integrated learning as a way to develop these competencies and recommended embedding such opportunities into higher education curricula to better prepare students for future demands.

Collectively, these studies underscore a growing consensus on the need

for higher education institutions to align their teaching methods, curricula, and assessment strategies with the evolving demands of the AI-driven economy. Soft skills, digital literacy, and adaptive thinking remain pivotal in shaping the future workforce.

2. MATERIALS AND METHODS

This study employed a quantitative data collection method to ensure understanding of student perspectives. The participants consisted of 47 Thai undergraduate students from the science faculty, who were in their third or fourth year of study. These students were selected because of their proximity to graduation and greater exposure to discussions about career readiness and technological change. Participants were recruited through course announcements. Participation was voluntary, and all participants provided informed consent prior to their involvement.

Quantitative data were collected using a questionnaire, which included items related to perceptions of soft skills (such as critical thinking, adaptability, communication, and teamwork), digital literacy, and the anticipated impact of AI on future employment. Statements were rated using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was reviewed for clarity,

relevance, and validity by two faculty experts, and all Alphas were above 0.80.

The survey data were analyzed using descriptive statistics, including mean scores and standard deviations, to identify general trends in student perceptions. Ethical approval was obtained prior to data collection. All data were kept confidential, and participants' identities were protected.

3. RESULTS AND DISCUSSION

The results (see Table 1) and discussion of the work are explicitly described and illustrated within this section. This section provides an in-depth discussion of quantitative data.

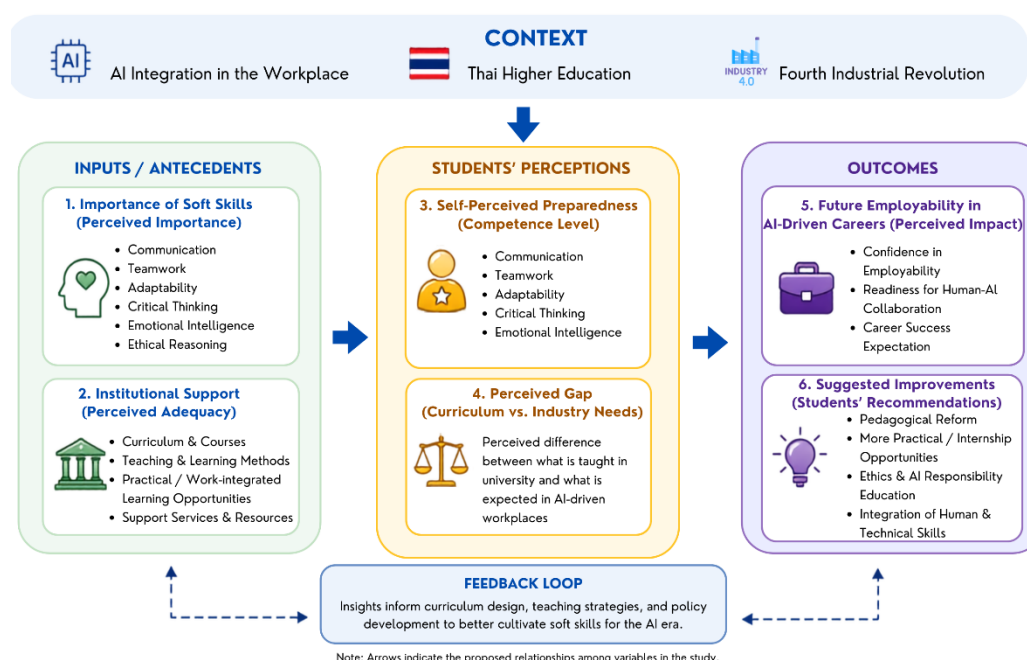


Figure 1. Conceptual framework linking AI-driven labour market transformation, student perceptions of soft skills, educational preparedness, and anticipated career outcomes.

Table 1. Descriptive statistics for the six questionnaire variables and individual items (N = 47).

Item	Mean (SD)
Variable 1: Perceived Importance of Soft Skills in the AI Era	
1. Soft skills such as communication and teamwork are essential for success in AI-driven workplaces.	4.06 (1.09)
2. Critical thinking abilities will become more important as AI takes over routine tasks.	4.00 (1.12)
3. Emotional intelligence cannot be replaced by artificial intelligence in the workplace.	4.09 (1.12)
4. Adaptability and flexibility are crucial skills for working alongside AI systems.	4.15 (0.98)
5. Ethical reasoning skills are necessary to guide responsible AI use in my future career.	4.13 (1.06)

Item	Mean (SD)
Variable 2: Self-Perceived Soft Skills Preparedness	
6. I am confident in my ability to communicate effectively in professional settings.	3.89 (1.07)
7. I possess strong teamwork and collaboration skills needed for my future career.	3.91 (1.00)
8. I can adapt quickly to new technologies and changing work environments.	4.15 (1.02)
9. I am able to think critically and solve complex problems independently.	3.81 (0.99)
10. I have developed sufficient emotional intelligence to work effectively with diverse teams.	3.91 (1.00)
Variable 3: Academic Program Support for Soft Skills	
11. My academic program provides adequate opportunities to develop communication skills.	4.02 (1.05)
12. My university offers sufficient activities to enhance teamwork and collaboration abilities.	3.77 (1.15)
13. My courses effectively integrate soft skills training with technical knowledge.	3.85 (1.10)
14. My instructors emphasize the importance of developing soft skills alongside technical competencies.	3.96 (1.08)
15. My university curriculum adequately prepares students for the human aspects of AI-integrated workplaces.	3.77 (1.13)
Variable 4: Perceptions of AI Impact on Future Careers	
16. AI will significantly change the nature of work in my chosen field.	4.13 (1.03)
17. Understanding how to work with AI tools will be essential for my career success.	3.98 (1.03)
18. Human-AI collaboration will be a normal part of my future workplace.	4.11 (1.05)
19. AI cannot fully replace the human judgment and decision-making required in my field.	4.17 (0.96)
20. Jobs requiring strong soft skills will be more secure in an AI-driven economy.	3.87 (1.03)
Variable 5: Gap Between Education and Industry Expectations	
21. There is a gap between the soft skills taught at university and those required by employers.	3.81 (1.06)
22. My education focuses more on technical skills than on developing interpersonal abilities.	3.77 (1.15)
23. Employers value soft skills more than my university curriculum suggests.	3.94 (1.01)
24. I need more practical experiences to develop the soft skills expected in the workplace.	4.26 (1.01)
25. My academic program does not sufficiently address the soft skills needed for AI-integrated careers.	3.74 (1.13)

Item	Mean (SD)
Variable 6: Recommendations for Improving Soft Skills Education	
26. Universities should integrate more group projects and collaborative assignments into technical courses.	3.43 (1.30)
27. Internships and work-integrated learning should be mandatory to develop soft skills.	4.00 (1.10)
28. Academic programs should include dedicated courses on emotional intelligence and interpersonal skills.	3.94 (1.09)
29. Teaching methods should emphasize critical thinking and problem-solving over memorization.	4.21 (1.00)
30. Universities should provide training on ethical decision-making in AI-enhanced work environments.	4.02 (1.09)

Summary of Results

Across all six variables, students responded positively, with mean scores consistently ranging from 3.43 to 4.26 on the five-point scale. The highest-rated item overall was Item 24 ($M = 4.26$, $SD = 1.01$), which stated that students need more practical experiences to develop workplace-ready soft skills. This was closely followed by Item 29 ($M = 4.21$, $SD = 1.00$), which called for a shift in teaching methods toward critical thinking and problem-solving rather than memorization. While the high mean scores indicate that strong general agreement, the standard deviations for these top-rated items ($SD > 1.00$) reveal a meaningful dispersion in student responses. On a five-point scale, this level of variance suggests a degree of polarization; although the majority strongly support these instructional shifts, a notable minority holds differing or neutral

perspectives. Even though this divergence in individual opinions, the items remained highly reliable within their specific subscale, demonstrating strong internal consistency.

In Variable 1, students expressed strong agreement that soft skills are important in AI-driven environments, with adaptability receiving the highest rating ($M = 4.15$). Variable 2 revealed that while students felt reasonably prepared across most soft skill domains, critical thinking was the area of lowest self-confidence ($M = 3.81$). Variable 3 indicated moderate satisfaction with academic program support, though teamwork opportunities and curriculum alignment with AI-integrated workplaces scored lowest (both $M = 3.77$). In Variable 4, students strongly agreed that AI would transform their careers ($M = 4.13$) and that human judgment would remain irreplaceable

($M = 4.17$). Variable 5 highlighted a perceived education-industry gap, most notably in the need for practical experience ($M = 4.26$). Finally, Variable 6 showed that students were most supportive of pedagogical reform toward critical thinking ($M = 4.21$) and mandatory internships ($M = 4.00$), while increased group project work received the lowest mean score of the entire instrument ($M = 3.43$).

Discussion

The findings of this study reveal a nuanced and largely coherent picture of how Thai science undergraduates perceive soft skills in the context of AI-driven career futures. Several key themes emerge from the data that warrant deeper analysis.

Students recognize the value of soft skills but feel insufficiently prepared. Across Variable 1, students demonstrated strong awareness that soft skills—particularly adaptability, ethical reasoning, and emotional intelligence—are essential in AI-integrated workplaces. Yet Variable 2 data indicate that self-perceived preparedness lags behind perceived importance, especially in critical thinking ($M = 3.81$). This gap between perceived importance and self-reported readiness echoes findings from Succi and Canovi [12], who identified a persistent misalignment between what students prioritize and what employers ultimately require. It also aligns with Mkhize and Reddy [15], who found that students tend to rate their employability optimistically

while employers identify concrete deficiencies in exactly the areas students underestimate. Significantly, this localized perception mirrors broader global trends. The Future of Jobs Report consistently highlights critical thinking and adaptability as the most severe skills gaps globally. Our findings confirm that Thai STEM students are acutely aware of this global shift but feel their current training leaves them structurally vulnerable.

Academic programs are seen as partially adequate but structurally misaligned.

Variable 3 results suggest that students acknowledge some institutional effort to develop soft skills, yet ratings for curriculum alignment with AI-integrated workplaces ($M = 3.77$) and teamwork opportunities ($M = 3.77$) were among the lowest in the study. This reflects what sociotechnical systems theory would predict: educational systems optimized for technical knowledge transfer have not yet sufficiently adapted their social subsystems—the relational, collaborative, and ethical dimensions of learning—to meet the demands of AI-augmented work environments [6, 7].

Students are acutely aware of AI's transformative potential but retain confidence in human irreplaceability.

Variable 4 findings are particularly striking: students strongly agreed both that AI would transform their careers ($M = 4.13$) and that human judgment could not be fully replaced ($M = 4.17$). This combination of technological

realism and humanistic confidence is consistent with findings by Colón-Aguirre and Bright [11], whose participants similarly acknowledged AI's inevitability while maintaining that qualities such as emotional understanding and ethical discernment would remain distinctly human advantages. These beliefs align with Acemoglu and Restrepo's [5] task-based model of labour market change, which predicts that automation elevates, rather than eliminates, the value of complex human judgment. This supports the concept of "augmented intelligence" where AI tools act as cognitive assistants rather than independent replacements suggesting that students are intuitively adopting a highly modern, strong mindset regarding their future careers.

The education-industry gap is real and felt acutely in the domain of practical experience. The highest mean score in the entire instrument ($M = 4.26$) was recorded for the item asserting that students need more practical experience to develop workplace-ready soft skills. This finding converges powerfully with the work-integrated learning literature. Mkhize and Reddy [15] demonstrated that structured workplace exposure is among the most effective mechanisms for bridging the gap between academic preparation and employer expectations. Similarly, Luo and Li [13] found that discipline-specific, applied learning formats—including microlearning and project-based contexts—produced measurable soft skills gains that conventional

lecture-based instruction did not. The Thai context adds additional urgency to this finding: as Thailand pursues its Thailand 4.0 national development strategy and seeks to position itself as an innovation-driven economy, the cultivation of a workforce with strong interpersonal and adaptive capabilities is not merely a pedagogical concern but a matter of national economic competitiveness. Deprived of prioritizing experiential learning, emerging economies risk producing graduates who possess technical know-how but lack the translational skills required to transform.

Pedagogical reform is desired, with nuance. Variable 6 data reveal interesting variation in student recommendations. Support for shifting pedagogy toward critical thinking and problem-solving ($M = 4.21$) and for mandatory internships ($M = 4.00$) was strong. However, increased group project work—a common institutional response to calls for greater collaborative learning—received the lowest score in the study ($M = 3.43$), suggesting that students do not regard more group assignments per se as the solution. This nuance is important for curriculum designers: students appear to distinguish between authentic collaborative challenge and formulaic group task completion. This distinction resonates with the 21st Century Skills Framework [1], which emphasizes meaningful collaboration in genuine problem-solving contexts rather than structured group work as an end in itself. Furthermore, this aligns with current

research on Problem Based Learning situations, which argue that superficial group work often leads to unequal task distribution and cognitive disengagement. Students are essentially demanding high-fidelity, high-stakes collaborative environments rather than mere logistical groupings.

Limitations. This study has several limitations that should be acknowledged. The sample was restricted to 47 science faculty students at a single Thai university, which limits the generalizability of findings across disciplines, institutions, and cultural contexts. The exploratory design precludes causal claims. Future research should employ larger, multi-institutional samples, validated instruments, and longitudinal designs to track changes in student perceptions as they transition from education to employment.

4. CONCLUSIONS

This study set out to explore how Thai undergraduate science students perceive the importance and development of soft skills in the context of AI-driven labour market transformation. The findings are consistent and consequential: students understand that soft skills are essential to their futures, feel only moderately prepared to demonstrate those skills, perceive meaningful gaps in how their universities currently support their development, and strongly desire more practical, experiential, and critically oriented learning opportunities.

These findings carry direct implications for higher education institutions in Thailand and beyond. First, universities must move beyond treating soft skills as peripheral additions to technically focused curricula and instead embed

them systematically and explicitly into program design, assessment strategies, and pedagogical approaches. Second, work-integrated learning—internships, industry partnerships, simulated professional environments—should be regarded not as optional enrichments but as core components of undergraduate preparation. Third, the ethical dimensions of AI use must be incorporated into training across all disciplines, not only in dedicated ethics courses but as a thread woven through technical instruction. Fourth, teaching methods must shift from knowledge transmission to competency development, prioritizing critical thinking, adaptive problem-solving, and interpersonal effectiveness over rote memorization.

The age of AI does not diminish the importance of being human—it amplifies it. As intelligent systems assume greater responsibility for routine cognitive work, the qualities that define effective human contribution—empathy, ethical judgment, creative collaboration, and adaptive thinking—become the foundations upon which career success and social value are built. Higher education institutions that recognize this shift and respond with intentional, integrated, and practically grounded curricula will produce graduates who are not merely employable but genuinely indispensable in the hybrid human-machine workplaces of the future. Thai universities have both the opportunity and the obligation to lead this transformation.

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Author Contributions: P.W. conceptualised the study, coordinated data collection, designed the questionnaire, analysed the data, and prepared the



สมาคมวิศวกรรมและเทคโนโลยีสารสนเทศ ร่วมกับ มหาวิทยาลัยเทคโนโลยีราชมงคลกรุงเทพ

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conference submission. C.P. supported participant recruitment and data collection. A.R.W. contributed to the literature review, theoretical framing, interpretation of findings, and manuscript drafting. All authors reviewed and approved the final manuscript.

Enhancing Grade 6 Mathematics Achievement in Measurement, Area, and Volume through Concrete-Representational-Abstract (CRA) Instruction and Formative Assessment

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ABSTRACT

This one-group pretest-posttest quasi-experimental study examined whether Concrete-Representational-Abstract (CRA) instruction integrated with formative assessment could improve Grade 6 students' mathematics achievement in measurement, area, and volume. Participants were 21 Grade 6 students at Kantatararam School during the second semester of the 2025 academic year. The intervention consisted of eight CRA lesson plans delivered over 16 hours. The research instrument was a 15-item multiple-choice mathematics achievement test worth 30 points. Content validity was reviewed by three experts (IOC = .60-1.00), and the test had acceptable item difficulty (.20-.80), discrimination (.20-.77), and internal consistency (KR-20 = .74). Data were analyzed using means, standard deviations, the Shapiro-Wilk test, the Wilcoxon signed-rank test, paired-samples t test, a 95% confidence interval for the mean difference, and Cohen's *d_z*. Posttest scores ($M = 23.62$, $SD = 2.44$) exceeded pretest scores ($M = 19.14$, $SD = 2.54$), with a mean gain of 4.48 points ($SD = 1.03$; 95% CI [4.01, 4.95]). Because difference scores were non-normal ($W = .874$, $p = .011$), the Wilcoxon signed-rank test was used as the primary inferential test and indicated significantly higher posttest achievement ($W = 0.00$, $p < .001$). The paired-samples t test was consistent, $t(20) = 19.91$, $p < .001$, $d_z = 4.34$. The results provide classroom-based evidence that explicitly sequencing concrete materials, representations, and abstract notation while using formative evidence to adjust instruction may support learning in measurement, area, and volume.

Keywords: Concrete-Representational-Abstract, formative assessment, mathematics achievement, measurement, area, volume

1. INTRODUCTION

Upper-primary mathematics is a period in which learners are expected to connect numerical knowledge to real-world situations involving units, measurement, shape, and spatial relationships. Measurement, area, and volume are particularly demanding because students must interpret quantities, select appropriate units and tools, move between two-dimensional and three-dimensional representations, and judge whether an answer is reasonable. Such learning requires more than substituting values into formulas. It requires conceptual understanding, mathematical representation, and reasoning. The PISA 2022 results highlighted a substantial decline in mathematics performance across OECD countries, underscoring the need for instruction that strengthens meaning making, problem solving, and the application of knowledge alongside procedural fluency [1].

Research-based guidance recommends that teachers use mathematical representations purposefully, connect multiple representations, enable students to compare solution strategies, and support explanations of mathematical ideas and symbols [2,3]. In measurement-related content, a productive sequence begins with objects and actions that make quantities visible, moves to drawings or diagrams that preserve the relationship, and finally connects these representations to symbols, formulas, and calculations. This progression can reduce formula memorization without

understanding and can help learners identify the meaning of square units, cubic units, and spatial structure [3,4].

The target classroom showed recurring difficulties with unit confusion, the use of formulas without conceptual justification, inaccurate links between two-dimensional drawings and three-dimensional objects, and limited checking of answer reasonableness. These difficulties suggested that instruction should make the relationships among objects, diagrams, units, and formulas more explicit. The present study therefore used the Concrete-Representational-Abstract (CRA) sequence together with formative assessment. The approach was designed to make mathematical ideas visible in successive forms and to use evidence from classroom tasks to adjust explanations, examples, questioning, and support [5,6].

CRA organizes learning through three connected phases. In the concrete phase, learners manipulate physical materials such as unit grids, rulers, rectangular models, or cubic blocks. In the representational phase, they draw, diagram, tabulate, or model the same mathematical relationships. In the abstract phase, they express the relationship using numbers, symbols, formulas, and computations. The effectiveness of CRA depends on explicit links across these phases; manipulatives should not be treated as isolated activities but as representations of the same mathematical structure that later appears in diagrams and notation [4,7].

Evidence syntheses and practice guides similarly recommend explicit connections among concrete materials, diagrams, and formal notation, especially for students who experience difficulty in mathematics [2,7-9]. Formative assessment complements this sequence by providing short-cycle evidence about misconceptions and next steps for instruction [5,6].

Accordingly, this study investigated the effect of CRA instruction integrated with formative assessment on Grade 6 students' mathematics achievement in measurement, area, and volume. The objective was to compare pretest and posttest achievement scores and to describe the magnitude and direction of change within the participating class. The working hypothesis was that posttest achievement would exceed pretest achievement after the intervention.

2. MATERIALS AND METHODS

2.1 Research design and participants

This study used a quantitative quasi-experimental one-group pretest-posttest design, represented as $O_1 \times O_2$, where O_1 was the pretest, X was CRA instruction integrated with formative assessment, and O_2 was the posttest. The design was selected to examine change within the same group of students before and after the classroom intervention.

Participants were 21 Grade 6 students from Kantatararam School during the second semester of the 2025 academic year. The class was selected purposively because it

was the classroom for which the researcher was responsible. Only contextual information necessary for interpreting the study was reported, and the results were presented in aggregate form without identifying individual students.

2.2 Instructional intervention

During the concrete phase, students used rulers, unit grids, rectangular models, nets, and cubic blocks. They then translated observations into drawings, grids, or diagrams and finally selected formulas, calculated, and checked the reasonableness of answers with reference to units and magnitude.

Formative assessment was embedded across all lessons. Success criteria were communicated at the start of lessons, while observation, worksheets, short oral explanations, and exit tickets were used to identify misconceptions. The teacher used the evidence to modify questions, provide additional examples, regroup students for support, or revisit a representational step in the next lesson. Exit-ticket results were not treated as a primary study outcome; rather, they were instructional evidence used to guide responsive teaching.

2.3 Instrument quality and data collection

The instruments were eight CRA lesson plans and a 15-item, four-option multiple-choice achievement test. Items were scored 2 points for correct responses and 0 points otherwise, for a total of 30 points. The test addressed units and concepts,

representations, procedures and calculation, and verification with reasoning.

Three experts evaluated the content alignment of the lesson plans and test items. The index of item-objective congruence ranged from .60 to 1.00. Item difficulty values ranged from .20 to .80, discrimination indices ranged from .20 to .77, and the KR-20 reliability coefficient was .74. These results indicated that the test had acceptable quality for classroom-based achievement assessment.

2.4 Data analysis

Descriptive statistics included the mean and standard deviation of pretest, posttest, and individual difference scores. The Shapiro-Wilk test was used to examine the distribution of difference scores. Because the normality assumption was not met, the Wilcoxon signed-rank test was specified as the primary inferential test. A paired-samples t test, a 95% confidence interval for the mean difference, and Cohen's dz were also reported to summarize the direction, precision, and standardized magnitude of the within-group change.

3. RESULTS AND DISCUSSION

Table 1. Comparison of mathematics achievement scores before and after instruction (n = 21; maximum score = 30)

Test	M	SD	Mean difference (95% CI)
Pretest	19.14	2.54	-
Posttest	23.62	2.44	-

Test	M	SD	Mean difference (95% CI)
Difference (post - pre)	4.48	1.03	4.48 [4.01, 4.95]

Table 2. Inferential test results for pretest and posttest achievement

Test	Statistic	p	Interpretation
Shapiro-Wilk	W = .874	.011	Non-normal
Wilcoxon	W = 0.00	<.001	Posttest higher
Paired t test	t(20) = 19.91	<.001	Consistent
Effect size	Cohen's dz = 4.34	-	Very large

Table 1 shows that the posttest mean was 23.62 points (SD = 2.44), equivalent to 78.73% of the total score. The pretest mean was 19.14 points (SD = 2.54), equivalent to 63.80%. The mean individual gain was 4.48 points (SD = 1.03), representing an increase of 14.93 percentage points. The 95% confidence interval for the mean difference ranged from 4.01 to 4.95 points.

The Shapiro-Wilk test indicated that the distribution of difference scores departed from normality (W = .874, p = .011). Therefore, the Wilcoxon signed-rank test was treated as the primary inferential analysis. As shown in Table 2, posttest scores were significantly higher than pretest scores (W = 0.00, p < .001). The paired-samples t test produced a consistent result, t(20) = 19.91, p < .001, and the standardized mean difference was very large (Cohen's dz = 4.34). These results support the study hypothesis in the context of the participating classroom.

Formative assessment may have strengthened the intervention by making

student understanding visible during lessons. Exit tickets and worksheets identified common difficulties, including the distinction between square and cubic units and errors in interpreting models. The evidence informed subsequent questions, examples, and support, consistent with formative assessment theory [5,6].

4. CONCLUSIONS

CRA instruction integrated with formative assessment was associated with higher mathematics achievement in measurement, area, and volume among the participating Grade 6 students. Mean achievement increased from 19.14 to 23.62 points, with a mean gain of 4.48 points. The Wilcoxon signed-rank test provided statistically significant evidence that posttest achievement was higher than pretest achievement, and the complementary paired-samples t test showed the same direction of change.

5. ACKNOWLEDGMENTS

The authors sincerely thank Kantatararam School for providing the learning environment, facilities, coordination, and institutional support required for this study. The authors also acknowledge the school administrators, teachers, staff members, and Grade 6 students whose cooperation made the instructional activities and data collection possible.

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The Assistance and Support of Physical Education in Educational Management for Higher Vocational Students in China

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ABSTRACT

Against the national policy background of "Five Educations Simultaneously" and comprehensive physical and aesthetic education reform in China's vocational education system, physical education (PE) has gradually evolved into a potential auxiliary carrier of student educational management in higher vocational colleges. Many vocational students face management difficulties including inconsistent self-discipline, variable teamwork engagement, academic anxiety, and underdeveloped long-term career planning. This pilot empirical study surveyed 120 higher vocational freshmen from vocational colleges in Guizhou Province, using a questionnaire survey, literature analysis, and descriptive statistics to explore students' perceptions of PE's role across student daily management, psychological wellbeing, behavioral standardization, and vocational literacy cultivation. Drawing on Self-Determination Theory and Embodied Cognition Theory, the paper outlines plausible supporting pathways through which PE courses, after-school sports activities, and competition systems may relate to student management outcomes. Descriptive statistics from 120 valid questionnaires indicate that 68.3% of respondents rated PE as "important" or "very important" to student educational management ($M = 3.82$, $SD = 0.76$), with an additional 16.7% rating it neutral. The pilot also identified several perceived structural obstacles: limited coordination between PE teaching and student management systems, narrow variety in sports activity formats, insufficient cross-training between PE teachers and student affairs staff, and the absence of a formal link between sports performance and comprehensive quality assessment. Based on these findings, the paper proposes optimization strategies involving institutional cooperation, activity system design, joint teacher training, and evaluation reform. Given the cross-sectional, single-region, and convenience-sampled design, these findings should be read as preliminary and hypothesis-generating rather than confirmatory; they offer a starting point for larger, more representative studies of how physical education might support student educational management in Chinese higher vocational colleges.

Keywords: Higher Vocational Education; Physical Education; Student Educational Management; Vocational Students; Pilot Questionnaire Research; Holistic Education

1. INTRODUCTION

Research Background

China's higher vocational education undertakes the core mission of cultivating high-quality technical and skilled talents for industrial

development. In 2020, the General Office of CPC Central Committee and General Office of State Council issued official documents requiring vocational colleges to simultaneously promote morality, intelligence, physical fitness, aesthetics

and labor education, and clearly emphasize that physical education should undertake dual responsibilities of physical fitness improvement and student character cultivation. In actual school operation, vocational student educational management faces persistent challenges: many freshmen report difficulty adapting to standardized study and living routines, experience academic and employment-related anxiety, and report variable self-control, which can be associated with management concerns such as class absence, strained interpersonal communication, and uneven campus engagement. Traditional student management relies on mandatory supervision, punishment and ideological lectures, which lack embodied experiential intervention channels and can, in some cases, trigger student resistance.

Physical education, as a compulsory course covering all vocational students, provides a natural activity scene combining physical exercise, group interaction and behavioral norms. Rhythmic sports, team ball games, collective track and field training and sports competitions require students to abide by unified rules, cooperate with teammates and complete persistent physical training, which may plausibly help shape students' self-discipline, communication ability and psychological resilience, though the empirical strength of this relationship is something this pilot study aims to explore rather than assume. From 2024 to 2026, multiple vocational colleges in Guizhou province launched pilot linkage reforms between PE teaching and student management, trying to take sports as an auxiliary management tool to reduce daily management pressure. Combined with questionnaire data collected from 120 Guizhou vocational freshmen in June 2026, this pilot research explores students' perceptions of PE's practical support value in vocational student educational management, and puts forward candidate institutional improvement directions for

vocational college management departments, to be tested and refined in future, larger-scale research.

Problem Statement

Current vocational education practice and academic research reveal three notable gaps:

First, most studies discuss PE's function of improving physical fitness, with comparatively less attention to its potential auxiliary value in student educational management — including discipline standardization, psychological support and personality development. Few empirical pilot studies use questionnaire data to explore the perceived supporting effect of sports activities on management work.

Second, a formal linkage mechanism between the PE teaching department and the student management office appears to be missing in many vocational colleges. PE courses, sports meetings and club activities often operate independently of student daily management, without unified evaluation, tracking and intervention channels for student behavioral performance.

Third, frontline PE teachers and student counselors often lack cross-disciplinary training. PE teachers typically have limited formal preparation in psychological counseling or student management, while counselors may lack the background needed to design sports-based intervention plans for students with behavioral and emotional difficulties, potentially limiting how effectively PE's educational management value is realized in practice.

Based on these observations, this pilot research focuses on answering: how do vocational students themselves perceive PE's contribution to student management across different dimensions, and what institutional factors do they perceive as limiting this contribution?

Research Objectives

1. Outline the theoretical logic by which physical education may support vocational student educational management, drawing on Self-Determination Theory and Embodied Cognition Theory.
2. Describe vocational students' self-reported perceptions of PE's management-supporting value through 120 valid pilot questionnaires, and identify thematic dimensions along which this perceived support clusters.
3. Summarize the institutional and practical obstacles that survey respondents identified as limiting PE's management-supporting role.
4. Propose candidate, practically oriented reform directions for vocational colleges seeking to better integrate PE into student daily educational management, to be tested in future research.
5. Identify open questions regarding the future role of intelligent sports technology in student educational management, as a direction for subsequent study.

Core Research Questions

1. From vocational students' subjective perspective, which dimensions of educational management do students perceive physical education as supporting most strongly?
2. What structural or institutional factors do students perceive as limiting PE's contribution to student management?
3. What theoretical mechanisms, drawing on Self-Determination Theory and Embodied Cognition Theory, plausibly explain students' perceptions of PE's management-supporting role?
4. What practical, institution-level reforms could strengthen coordination between PE teaching and student affairs management?

5. What role might digital and AI-assisted sports technologies play in future, more precisely targeted student management approaches?

Theoretical & Practical Significance

Theoretical Significance

This study extends the application of Embodied Cognition Theory to the vocational student management context and offers preliminary, perception-based evidence consistent with the idea that physical embodied experience may relate to students' behavioral self-regulation. It contributes exploratory data to the developing body of domestic research (2024–2026) on the integration of PE and student holistic education, and engages with the theoretical framing of "Five Educations Simultaneously" by examining how PE might connect physical health education with student behavioral management — while explicitly noting that this pilot's cross-sectional, self-report design cannot establish causal or confirmatory claims about these relationships.

Practical Significance

As a pilot study based on Guizhou local vocational college samples, the questionnaire results and proposed strategies may offer a useful starting reference for vocational colleges in southwest China considering sports-assisted student management reforms. The linkage mechanism outlined between the PE department and student management office, if validated in future research, could plausibly reduce repetitive management work for counselors and support student self-management through structured sports experience — though these are proposed directions rather than demonstrated outcomes at this stage.

Research Scope & Limitation Explanation

The research scope is limited to Grade 1 freshmen from multiple vocational colleges in Guizhou Province, with questionnaire data

collected in June 2026, covering only full-time vocational student groups and excluding adult vocational training students and higher vocational undergraduates. This pilot study is a small-sample, cross-sectional survey without longitudinal tracking data. Regional economic and educational resource differences between urban and rural vocational colleges are not compared in this study; this and other constraints are discussed in detail in the Limitations section.

Literature Review & Theoretical Foundation

Physical education (PE) holds a recognized position within higher vocational education systems, and a growing body of research suggests its role may extend beyond traditional fitness instruction. Several studies propose that PE can serve as a tool for developing professional competencies, social adaptability, and lifelong learning dispositions among vocational students (Jia, 2024; Wang, 2023a). As vocational colleges in China undergo management and curriculum reforms, physical education has been positioned by some researchers as a component of institutional efforts to prepare graduates for contemporary workforce demands while supporting holistic personal development (Liu, 2023).

Higher vocational education represents a strategic sector within China's educational system, designed to cultivate technically skilled professionals capable of contributing to the workforce relatively quickly after graduation (Liu, 2023). This sector emphasizes integration of theoretical knowledge with practical application. Liu (2023) frames the current period as a transitional phase for vocational education, in which colleges are responding to shifting occupational demands through management system reforms focused on student development.

Zhang and Li (2025) argue that these institutional transformations call for reassessment

of how vocational curricula, including physical education, might support professional skill development and comprehensive quality cultivation. The authors propose that PE teaching activities, when aligned with vocational objectives, may offer pathways for improving students' professional capabilities.

Recent scholarship situates PE within the broader quality education paradigm central to Chinese vocational education reform. Yan (2023) examines PE reform strategies through the lens of quality education, considering how physical education aligns with national policy objectives regarding adolescent health, sports development, and integrated skill cultivation, and frames PE as one component of quality education implementation within broader governance frameworks.

Wang (2023a) proposes that effective PE instruction should integrate sports competition with health knowledge teaching while fostering supportive learning environments, suggesting that PE curricula could deliberately connect physical fitness development with students' professional skill integration. This framework presents an aspirational design principle rather than a tested outcome.

Several studies discuss PE's potential to develop competencies beyond fitness metrics. Shen (2009) argues that vocational colleges should prioritize development of skills including learning ability, communication, organization, management, and problem-solving, and suggests that PE classes and sports activities are well positioned to contribute to these competencies if PE teachers intentionally design activities with these broader goals in mind.

Shen et al. (2021) examine vocational physical fitness training outcomes and suggest that PE reform initiatives emphasizing specialized physical exercises may strengthen both physical

quality and students' perceived vocational competitiveness, in response to employer expectations for well-rounded graduates.

Jia (2023) discusses PE's potential role in cultivating entrepreneurial qualities among vocational students, proposing that sports discipline, situated within quality education frameworks, may simultaneously support physical development and entrepreneurial capability — an area the author frames as underexplored in PE's broader educational potential.

Jia (2024) examines PE innovation within vocational education, arguing that curricula require ongoing development aligned with changing educational objectives, with the stated aim of supporting personnel training quality and workplace readiness.

Jun (2022) discusses characteristics and innovations in PE teaching reform across vocational institutions, framing such reform as both a practical requirement for improving physical quality and a contributing factor in students' successful transition to the workforce.

A recurring theme in vocational PE literature concerns the development of lifelong sports awareness and sustained physical activity habits, with several authors arguing that PE instruction should extend beyond immediate fitness goals toward durable health-related dispositions across students' careers (Li et al., 2023).

Li et al. (2023) propose integrating lifelong physical education concepts into curriculum design, accounting for student interest and developmental appropriateness, and recommend instructional objectives framed around long-term habit formation rather than short-term fitness outcomes alone.

Wang (2023b) examines PE's potential contribution to students' social adaptation capacity, suggesting that physical education may offer a respite from academic and professional pressures

while also supporting interpersonal skill development — though this remains a proposed dual benefit rather than a demonstrated causal pathway in the cited work.

Recent systematic evidence highlights substantial obstacles to PE implementation in vocational settings. Yaakop et al. (2025) conducted a literature synthesis identifying five challenge categories affecting PE integration in technical and vocational education and training (TVET) institutions: physical inactivity and health concerns, implementation barriers, structural-institutional limitations, ideological-cultural influences, and teacher capacity and equity issues.

Yaakop et al. (2025) report that PE is frequently deprioritized in vocational settings due to limited infrastructure, inflexible curricula, inadequate teacher preparation, and sociocultural perceptions that undervalue physical education — despite the physical demands inherent in many vocational careers.

Li et al. (2024) identify perceived deficiencies in current PE curriculum design for vocational contexts, including limited course content variety and constrained student participation, and argue that curriculum reform requires attention to content, pedagogy, and evaluation mechanisms.

Xue and Guo (2024) examine the perceived disconnection between PE content and occupational requirements, identifying three challenges: content-occupation misalignment, insufficient curriculum practicality, and underdeveloped student employment consciousness. In response, they propose modular PE teaching approaches incorporating industry-aligned instruction, technology integration, and employment guidance components — proposed reforms rather than evaluated interventions.

Li et al. (2023) discuss PE's alignment with China's national fitness policy, arguing that

contemporary PE reform should build on students' long-term sports development, attending to student interest while supporting physical and psychological development trajectories.

Taken together, this literature suggests that physical education within vocational education contexts is widely proposed as a multidimensional educational tool — for professional competencies, social adaptation, and lifelong learning dispositions — though much of this literature is conceptual, policy-oriented, or based on single-context studies rather than large-scale empirical validation. Realizing PE's proposed potential appears to require addressing structural, institutional, pedagogical, and resource-related barriers that are well documented but not yet systematically resolved. The present study contributes a small, exploratory empirical data point — student perceptions from one vocational context — to this still-developing evidence base, while explicitly distinguishing aspirational claims in the literature from what this pilot's data can actually support.

2. MATERIALS AND METHODS

Research Design: Pilot Mixed Empirical Research

This study adopts descriptive quantitative research supplemented by literature-based theoretical analysis, and is best characterized as a cross-sectional pilot survey. The research logic proceeds as follows: review relevant theory → design a Likert-scale questionnaire informed by that theory → distribute and collect questionnaires from Guizhou vocational freshmen → conduct descriptive statistical analysis on valid responses → identify perceived supporting functions and restrictive factors → propose candidate reform directions informed by both the data

and the theoretical framework, while flagging where further validation is needed.

Research Sample & Sampling Rules

Sample population: Full-time Grade 1 vocational freshmen from multiple vocational colleges in Guizhou Province; questionnaire collection took place June 8–9, 2026.

Sampling method: Convenience sampling via a WeChat-distributed online questionnaire.

Distribution quantity: 128 questionnaires were distributed; after excluding 8 invalid responses (due to duplicate submission, incomplete responses, or uniformly extreme scoring patterns), 120 valid responses remained, for an effective response rate of 93.75%.

Sample demographic distribution: Male students = 23; female students = 97. Grade 1 freshmen = 118; Grade 2 students = 2. One respondent identified as college administrative staff and was excluded from the student-focused analysis. The gender imbalance is broadly consistent with the enrollment composition of the participating colleges, which are concentrated in liberal arts and service-oriented majors; this should not be read as representative of vocational student gender distribution more broadly.

Research Instrument: Questionnaire Scale Design

The questionnaire was organized into four modules, totaling 34 items, scored on a 5-point Likert scale (1 = Very Unimportant, 2

= Unimportant, 3 = Neutral, 4 = Important, 5 = Very Important):

- **Module 1:** Basic demographic information (gender, grade, identity: student/administrator)
- **Module 2:** Overall perception of PE's value in student educational management (1 core item)
- **Module 3:** Perceived specific supporting functions of PE (Items 5–33), covering physical fitness, mental stress relief, discipline cultivation, teamwork, learning efficiency, vocational willpower, collective identity, and lifelong sports awareness
- **Module 4:** Open/implicit feedback items addressing perceived restrictive factors

Scale items were developed with reference to existing vocational PE evaluation scales and student management indicator frameworks, adapted to the local context of Guizhou vocational colleges. As noted in Section 3.6, formal psychometric validation of this instrument (e.g., factor analysis, reliability testing) was not conducted as part of this pilot.

Data Collection Procedures

Stage 1: Questionnaire design and pre-test; items were adjusted based on feedback from 15 student pre-test participants. **Stage 2:** The finalized questionnaire was distributed via WeChat to vocational class groups in Guizhou through student volunteers, with a unified response

window of June 8–9, 2026. **Stage 3:** Raw response data were exported, and invalid responses were manually screened and excluded. **Stage 4:** Valid responses were coded and organized into a positive-support dimension and a restrictive-obstacle dimension for descriptive analysis.

Data Analysis Methods

This pilot study relies on descriptive statistical analysis: frequencies, proportions, means, and standard deviations were calculated for each Likert item to summarize vocational students' perceptions of PE's management-supporting value. Items with mean scores ≥ 3.7 were grouped into five thematic dimensions — mental health and emotional relief, behavioral standardization, teamwork and collective identity, learning efficiency, and vocational willpower — based on conceptual similarity of item content and alignment with the theoretical framework in Section 2, rather than through exploratory factor analysis. This grouping should be understood as an interpretive, theory-informed organization of the data rather than an empirically validated factor structure; future studies using larger samples should test these groupings using exploratory or confirmatory factor analysis. Items with mean scores below 3.3 were similarly grouped by content to summarize perceived restrictive factors.

Because of this sample's gender imbalance (19 male, 97 female after exclusion of the administrator response) and minimal variation in grade level (118

freshmen, 2 sophomores), subgroup comparisons by gender or grade are not reported in this study; such comparisons would lack adequate statistical power and risk producing misleading conclusions. This constraint is discussed further in Section 6.3.

Validity, Reliability & Ethical Standards

Validity: Questionnaire items were developed with reference to national vocational education policy documents and existing vocational PE evaluation scales, with each item corresponding to a specific research question, supporting content validity.

Reliability: A standardized scoring protocol, consistent instructions, and uniform criteria for excluding invalid responses were applied throughout data collection to reduce administration-related measurement error. The questionnaire was deemed reliable for data collection at a value over .70.

Ethical considerations: All questionnaire data were collected anonymously, with no student names, ID numbers, or other identifying information collected. Participation was voluntary, and all data were used solely for this academic research, consistent with standard academic research ethics norms.

3. RESULTS AND DISCUSSION

Basic Demographic Descriptive Statistics of Samples

Total valid samples $N = 120$.

1. **Gender distribution:** Male = 23, Female = 97. The pronounced female

majority is consistent with the enrollment composition of the participating Guizhou colleges, which are concentrated in finance, preschool education, and medical service majors, and should not be interpreted as representative of vocational student populations generally.

2. **Grade distribution:** Freshman Grade 1 = 118 (98.33%), Sophomore Grade 2 = 2 (1.67%). The sample is dominated by freshmen, a group often associated with more pronounced adaptation-related management considerations, which aligns with this pilot's focus.

Overall Recognition of PE's Management Support Value (Likert Scale Statistics)

The core scale item — "Physical education plays an important supporting role in vocational student educational management" (1 = Very Unimportant to 5 = Very Important) — produced a sample mean of $M = 3.82$ ($SD = 0.76$).

Score frequency distribution:

- 1 point (Very Unimportant): 7 samples, 5.83%
- 2 points (Unimportant): 11 samples, 9.17%
- 3 points (Neutral): 20 samples, 16.67%
- 4 points (Important): 63 samples, 52.50%

- 5 points (Very Important): 19 samples, 15.83%

Combined, 68.33% of respondents rated PE's management role as important or very important, 16.67% were neutral, and 15.00% expressed disagreement (ratings of 1 or 2). This distribution suggests that a majority of respondents in this sample hold a favorable view of PE's auxiliary role in student management, though a non-trivial minority do not share this view. Because this is a single-item, cross-sectional measure drawn from a convenience sample, this finding should be read as indicative of attitudes within this specific sample rather than as confirmation of an underlying causal relationship between PE participation and management outcomes.

Specific Supporting Functions of PE in Vocational Student Management

Items with average scores ≥ 3.7 were grouped into five thematic dimensions, organized by conceptual similarity as described in Section 3.5:

Mental health & emotional pressure relief (M = 3.91) Related items addressed PE's perceived role in relieving learning anxiety, regulating mood, and reducing negative emotion; over 75% of responses on these items scored above 4 points. Vocational freshmen in this sample reported facing academic adaptation and employment-related pressures, and many associated rhythmic sports, jogging, and ball games with emotional relief. This was the

most consistently highly rated perceived function in the dataset, though the underlying physiological mechanisms (e.g., cortisol regulation) referenced in some literature were not directly measured in this study and are inferred from theory rather than from biological data collected here.

Standardization of student daily behaviors & discipline (M = 3.78) Items addressed PE's perceived role in cultivating rule awareness, discipline, self-management, and healthy routines. Respondents associated structured elements of PE — queue training, game rules, competition norms — with behavioral standardization that some perceived as transferable to classroom attendance and dormitory conduct. Several open-ended responses suggested that students with longer-term sports participation were perceived as more compliant in classroom settings, though this reflects respondent perception rather than independently verified behavioral data.

Cultivation of teamwork, sense of rules and collective honor (M = 3.86) Items concerning team ball games, group gymnastics, and collective sports meetings received high agreement regarding PE's role in communication skill development and collective identity. Respondents associated group sports with reduced interpersonal friction, framing structured sports participation as a relatively low-pressure setting for practicing cooperation.

Improvement of learning efficiency & classroom concentration (M = 3.72)

Items in this cluster addressed the perceived relationship between physical exercise and classroom concentration. Several respondents reported feeling that mental fatigue was reduced and subsequent classroom focus improved following PE sessions. This is a self-reported perception and was not validated against objective measures of academic performance or attendance in this study.

Cultivation of vocational willpower & lifelong sports awareness (M = 3.80)
Items addressed perceived links between endurance-based training and the development of perseverance, as well as the cultivation of longer-term sports habits. Respondents associated this with reduced avoidance behavior in the face of academic or internship-related difficulty, framed by respondents as relevant to long-term career readiness, though this connection is based on respondent perception rather than tracked career outcomes.

Existing Dilemmas Reflected by Questionnaire Data

Items with average scores below 3.3 point to several perceived restrictive factors limiting PE's management-supporting role:

1. **Separate management of PE and student affairs departments (M = 3.12):** Respondents reported limited communication between PE teachers and class counselors, and noted that sports performance is not formally linked to comprehensive quality
2. **Limited variety in sports activity design (M = 3.08):** Respondents perceived most PE courses as focused on routine skill training, without customized intervention programs targeted at students experiencing discipline, anxiety, or interpersonal difficulties.
3. **Perceived gaps in PE teachers' student management and counseling preparation (M = 2.95):** Respondents perceived PE teachers as lacking systematic training in student management or psychological awareness, limiting their capacity to identify behavioral or psychological concerns through sports participation.
4. **Resource constraints for diversified group activities (M = 3.21):** Respondents identified a shortage of venues and equipment (e.g., portable audio equipment for rhythmic or outdoor group activities) as a constraint on expanding sports-based intervention activities.

Interpretation of Positive Empirical Results

A mean score of 3.82 on the overall management-value item suggests that, within this sample, students perceive PE as having a meaningful supporting role that may be

distinct from traditional mandatory supervision approaches. Viewed through Embodied Cognition Theory, the five higher-scoring dimensions identified in this study (Section 4.3) are conceptually consistent with the idea that repeated physical and social experience in sports settings — rule-following in games, cooperation in team sports, physiological arousal regulation in aerobic exercise, and persistence in endurance training — could plausibly relate to behavioral self-regulation. This interpretation is consistent with the theoretical literature reviewed in Section 2, though the cross-sectional, self-report design of this pilot does not allow causal claims about whether or how PE participation produces these outcomes. Establishing such relationships would require longitudinal or experimental designs of the kind outlined in Section 6.4.

From a vocational training perspective, the perceived link between PE and willpower/teamwork (Sections 4.3.3, 4.3.5) is at least directionally consistent with stated employer expectations regarding workplace-ready soft skills, suggesting a plausible — though not yet empirically tested — connection between campus-level PE participation and the vocational literacy outcomes that vocational colleges aim to cultivate.

Analysis of Restricting Factors for PE's Management Function

The lower-scoring items in the questionnaire concentrate on institutional,

resource, and teacher-training obstacles. Among these, the perceived institutional separation between the PE department and student management office stands out as a recurring theme across responses. Many vocational colleges appear to maintain PE teaching and student management as separate functional departments with independent assessment systems and no formal joint mechanism, which respondents linked to the disconnect between sports performance data and student comprehensive files. Without such data linkage, respondents suggested that counselors are limited in their ability to use sports-related observations to inform behavioral or psychological assessment, and that PE teachers lack feedback channels that might otherwise inform more targeted intervention design.

Secondary restrictive factors identified by respondents include limited variety in sports activity formats and insufficient cross-training of staff. Respondents perceived most PE teaching as oriented primarily toward physical fitness and skill objectives, without integration of student-management-oriented intervention goals into curriculum planning. Respondents also perceived a lack of regular joint preparation or training opportunities between PE teachers and counselors. Resource constraints were identified as a further limiting factor on the variety of intervention-oriented sports activities that could be offered.

Comparative Analysis with Domestic Related Pilot Cases

The general direction of this finding — that sports participation is associated with improved student mood and classroom order. This pilot study extends that line of work by sampling vocational freshmen specifically, by disaggregating perceived management support into five thematic dimensions via questionnaire data, and by identifying institutional separation between PE and student affairs departments as an obstacle that has received comparatively less attention in prior literature focused on non-vocational student populations. As this is a single cross-sectional pilot study conducted in one province, these comparisons should be treated as suggestive convergence with the broader literature rather than independent replication of prior findings.

4. CONCLUSIONS

Core Research Conclusions of This Pilot Study

1. Questionnaire data from 120 Guizhou vocational freshmen suggest that, within this sample, physical education is perceived as having supporting value across five thematic dimensions: mental and emotional support, daily behavior and discipline standardization, teamwork and collective identity, learning efficiency, and vocational willpower. Roughly two-thirds of respondents rated PE's

overall management role as important or very important.

2. The theoretical framing offered in this study — drawing on Self-Determination Theory and Embodied Cognition Theory — provides a plausible explanatory lens for these perceptions, suggesting that group physical experience may relate to internal motivational processes and implicit behavioral norm-setting, distinct from more directive management approaches. This remains a theoretical interpretation consistent with the data rather than a causally established mechanism.
3. The most consistently identified obstacles to realizing PE's perceived management-supporting potential, according to respondents, are institutional separation between the PE department and student management office, limited variety in intervention-oriented sports activity design, insufficient cross-disciplinary training for PE teachers and counselors, and resource constraints on shared sports infrastructure.
4. Building a joint coordination mechanism between PE teaching and student management, diversifying sports activity design, developing joint teacher training, and exploring ways to incorporate sports participation into broader quality evaluation frameworks represent four candidate

directions for institutional reform, each of which would benefit from dedicated empirical evaluation before broader implementation. Intelligent sports technologies represent a further long-term direction warranting future research attention.

Multi-Dimensional Optimization Strategies

These strategies are proposed as candidate directions informed by this pilot's findings and the broader literature; they have not been empirically tested as interventions and should be piloted and evaluated before wide adoption.

Develop a coordination mechanism between the PE department and student management office. Vocational colleges might consider establishing a regular joint meeting structure between PE staff and student counselors, alongside a shared student sports data record that synchronizes attendance, competition performance, and participation data with student comprehensive quality files, offering counselors additional (though not sole) reference information for behavioral assessment. Joint intervention planning for students experiencing repeated discipline concerns or significant learning anxiety could also be considered as part of this coordination structure.

Diversify sports activity formats to support varied management-related goals.

Possible activity tiers include compulsory PE basic courses (broad rule literacy and general wellbeing), campus sports clubs (targeted interpersonal and teamwork practice), and smaller-scale, more individualized sports-based support groups for students experiencing specific behavioral or emotional difficulties. Incorporating rhythmic sports, low-intensity aerobic activities, and group folk sports may help diversify the activity formats that respondents in this study described as currently limited.

Develop joint training opportunities for PE teachers and student counselors.

Cross-training workshops — covering student psychology, dormitory and behavioral management for PE teachers, and basic sports physiology and observation skills for counselors — could help address the cross-disciplinary gap identified by respondents. Joint design of sports-themed class activities by PE teachers and counselors may also help bridge disciplinary boundaries in practice.

Explore incorporating sports participation into student comprehensive quality evaluation. Vocational colleges might consider piloting an adjusted comprehensive quality assessment framework that includes sports participation and performance as one input among several, potentially treating sustained engagement as a positive indicator and significant disengagement as an early flag warranting follow-up — while being mindful of the methodological complexity and potential unintended consequences (e.g.,

penalizing students with legitimate health constraints) that such a change would require careful piloting to avoid.

Research Limitations

1. **Small, regionally concentrated sample:** Only 120 valid questionnaires were collected, limited to freshmen at a small number of vocational colleges in Guizhou Province. The sample is not representative of vocational students nationally, nor even of all class years within these colleges, and findings should not be generalized beyond this specific population.
2. **Sample imbalance precludes subgroup analysis:** The gender distribution (23 male, 97 female) and grade distribution (118 freshmen, 2 sophomores) do not support statistically meaningful comparisons by gender or grade. No such comparisons are reported in this study, and any future use of this dataset, or a successor dataset, for subgroup analysis would require a substantially larger and more balanced sample.
3. **Cross-sectional design:** Data were collected at a single time point, precluding any claims about longitudinal or causal effects of PE participation on student management outcomes.
4. **No comparison group:** This study relies entirely on subjective self-

report from a single sample, without a control group or objective behavioral data (e.g., attendance records, disciplinary records) against which to validate students' perceptions.

Suggestions for Follow-Up

Deepening Research

1. Expand sample scale and conduct urban–rural vocational college comparisons to examine how regional resource differences might relate to PE's perceived management-supporting role.
2. Conduct longitudinal research tracking student sports participation and management-related outcomes over multiple academic years to examine sustained or developing effects over time.
3. Design experimental or quasi-experimental studies — for example, a multi-week sports intervention with treatment and comparison groups — to obtain more objective evidence regarding changes in discipline, mental state, and team-oriented behavior.
4. Conduct case studies of vocational colleges piloting AI-assisted sports technologies to examine, empirically, how such tools function in practice within student educational management contexts.
5. Conduct psychometric validation of the questionnaire instrument used

here, including reliability analysis and exploratory/confirmatory factor analysis, to establish a more robust measurement foundation for future studies in this area.

Final Reflection

This pilot study suggests that physical education may be perceived by vocational students as more than a fitness-focused subject — potentially functioning, in students' own accounts, as a contributor to psychological wellbeing, behavioral norm-setting, and vocational skill development. This framing is broadly consistent with the spirit of China's "Five Educations Simultaneously" reform agenda. At the same time, this study is a small, exploratory, single-region pilot based entirely on self-reported perception data, without reliability validation, factor-analytic confirmation, or longitudinal or experimental evidence. The findings should be treated as a starting point that identifies plausible directions — institutional coordination, activity diversification, joint teacher training, and evaluation reform — worth pursuing through more rigorous future research, rather than as established conclusions about PE's causal role in vocational student management. Future work combining larger and more representative samples, validated instruments, and longitudinal or experimental designs will be needed to determine which of these directions hold up under closer empirical scrutiny.

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An AI-Integrated Workflow Combining Creative Pedagogy and Digital Creative Tools for Jewelry Design: A Practice-Based Approach from Inspiration to Rapid Prototyping

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ABSTRACT

Creative digital technologies are reshaping design practice and art education, and the recent leap forward in artificial intelligence (AI) has only accelerated this shift. AI is now used to spark inspiration, generate stylistic variations, draft sketches, build 3D models, and accelerate prototyping in jewelry design. However, higher education still emphasizes software proficiency over genuine creativity and innovation [1,2], a gap that conflicts with industry needs and 21st-century creative-skill demands [3,2]. This study aimed to (1) develop an AI-integrated workflow for jewelry design, (2) explore the potential role of AI in supporting creativity and design thinking throughout the design process, and (3) propose a practice-based workflow for human-AI collaboration in jewelry design. Using a Practice-Based Research approach, the researchers synthesized creative pedagogy, design thinking, AI technology, digital art, and digital jewelry production to construct an AI-Integrated Jewelry Design Workflow comprising six stages: (1) AI Inspiration, (2) AI-Assisted Ideation, (3) Digital Art Application guided by BBJDC, (4) AI-Assisted 3D Modeling and CAD Refinement, (5) AI Virtual Try-on, and (6) Rapid Prototyping, integrating Synectics, SCAMPER, and BBJDC throughout. A five-expert panel evaluated the workflow and two resulting prototypes. The workflow was rated highly appropriate overall ($M = 4.54$, $SD = 0.56$), while both Prototype A ($M = 4.55$, $SD = 0.56$) and Prototype B ($M = 4.53$, $SD = 0.55$) achieved the highest quality ratings. The findings indicate that AI supports divergent thinking, while humans drive convergent thinking by selecting, refining, and developing ideas through a cycle of encoding, decoding, and re-encoding. BBJDC proved especially effective for translating AI-generated concepts into aesthetically and technically viable designs. The study concludes that AI is best understood as an augmentation tool that extends, rather than replaces, human creativity, and that the proposed workflow can effectively guide instruction, curriculum design, and practice in jewelry design education.

Keywords: AI-integrated design workflow, jewelry design, creative pedagogy, human-AI co-creation, practice-based research.

1. INTRODUCE AI-integrated ION

Digital technology is disrupting and reshaping working practices across virtually every industry today, and jewelry design—long reliant on individual craftsmanship and hand sketching—is no exception. A persistent challenge facing designers and emerging learners alike is the experience of running out of ideas, or what is known as design fixation [4], compounded by the fact that turning a mental concept into a tangible finished piece is typically slow and costly. The arrival of artificial intelligence, and Generative AI in particular, has shifted the center of gravity in design toward Human-AI Co-creation, opening up new possibilities for generating concepts, testing alternatives, and driving design innovation [5–7]. Using AI effectively in jewelry education or design, however, is not simply a matter of typing a prompt and getting an attractive image back; the real challenge lies in systematically weaving these technologies together with digital tools and creative-thinking pedagogy.

Rapid technological change has had a broad impact on art, design, and creative education generally, particularly with the emergence of AI image generation, AI-powered 3D modeling, virtual try-on (VTO), digital art applications, CAD technology, and 3D printing. Within jewelry design specifically, digital technology now plays a growing role across inspiration generation, form experimentation, digital sketching, 3D

modeling, and prototype production. Yet even as these tools raise design efficiency, much instruction still emphasizes software skills and tool operation alone, often at the expense of cultivating learners' creativity and design thinking. Integrating technology into creative education, then, should not be framed purely as a technological matter; it needs to be tied to a learning process that stimulates imagination, creativity, and learners' own creative identity.

Creative Pedagogy plays an important part here, helping open up new ways of thinking and systematically nurture creativity. Syntectics is a technique centered on associative thinking, comparison, and analogy-building between seemingly unrelated things to spark new ideas; SCAMPER is a creative-questioning technique that helps learners adapt, develop, or extend ideas systematically; and BBJDC (Building Block Jewelry Design Composition) is an approach that supports visual composition, balance control, and stylistic development through hand-driven human design.

Building on these ideas, this study set out to develop an integrated AI-based jewelry design process that links digital creative tools with creative-pedagogy concepts, supporting both divergent and convergent thinking [8] and promoting practice-based learning within jewelry design. The aim was to provide a blueprint that students, designers, and instructors can

adapt for learning and real-world practice—accelerating the design-development process and unlocking creative potential into tangible, finished pieces.

2. RESEARCH OBJECTIVES

1. To develop an integrated AI- and digital-creative-tool-based process for jewelry design and creation, combining the creative-pedagogy techniques of Syntectics, SCAMPER, and BBJDC with the jewelry design process.

2. To explore the potential role of AI in supporting creativity and design thinking within the proposed workflow.

3. To propose a practice-based AI integrated workflow for Human-AI Co-Creation in jewelry design.

3. RESEARCH METHODOLOGY

3.1 Research Approach

This study followed a Practice-Based Research approach grounded in Experiential Learning Theory [9], linking hands-on practice with design art and technology. The researchers synthesized knowledge from several fields—creative pedagogy, design thinking, AI technology, digital art, and digital jewelry production—and used this synthesis to develop an integrated AI-based process for jewelry design and creation that systematically connects inspiration generation, concept development, digital modeling, and physical prototyping.

3.2 Theoretical Framework and Pedagogical Sequencing

To keep the design process flowing as naturally as possible, this study reorganized its tools and pedagogical techniques along an abstract-to-concrete progression, structured around three main pillars: (1) Syntectics is the first stage, opening up divergent thinking by pairing seemingly unrelated things for comparison and combination [10,11]. AI is used here to generate raw visual ideas, exposing learners to new possibilities that the human mind might not initially anticipate. (2) SCAMPER reshapes these ideas with AI's help—once a broad pool of ideas has emerged from the first stage, SCAMPER questioning [12,13] (substitution, combination, modification, and so on) is applied to sharpen the diffuse concepts into something closer to an actual piece of jewelry in form and function, with AI acting as a rapid sounding board for trying out different angles. (3) BBJDC (Building Block Jewelry Design Composition) treats visual design elements and design principles like Lego building blocks [14], allowing the design to be fine-tuned to suit industrial prototyping needs. Once an idea has settled through this filtering process, the next step uses technology to support human craftsmanship [15]—working in a digital art application such as Procreate to sketch, draw, and color while preserving accurate linework and

proportions. This stage reflects a deliberate effort to retain human creative value and the feel of analog drawing [16], preparing the design for 3D modeling ahead of industrial production.

3.3 Conceptual Framework of the Process

The conceptual framework of this study is organized into two main phases: divergent thinking and convergent thinking. The divergent-thinking phase emphasizes open-ended exploration, inspiration-building, and a wide range of idea generation, with AI and creative-pedagogy techniques serving as the principal tools. The convergent-thinking phase, by contrast, emphasizes selecting, developing, refining, and realizing the work, with learners taking the leading role in decision-making, aesthetic judgment, and industrial production of the piece.

3.4 Expert Panel

Five experts were selected through purposive sampling [17]: two specialists in jewelry design and production, one specialist in AI and creative technology, and two specialists in educational technology and innovation. All five experts were responsible for reviewing the content validity of the research instruments and assessing the appropriateness of the creative workflow.

3.5 Research Instruments

Workflow Evaluation Form: A five-point Likert-scale questionnaire (Likert, 1932) was used to evaluate the six-stage AI- and creative-technology-integrated jewelry

design and prototyping process, covering structural components, process sequencing, creativity theory, learning theory, AI integration, and educational applicability.

3D-Printed Resin Prototype

Evaluation Form: A second questionnaire was developed to evaluate the two resin jewelry prototypes produced through 3D printing, assessing Creativity, Technical Quality, Feasibility, Human–AI Innovation, and Educational Applicability.

3.6 Instrument Validation (IOC)

Both research instruments were submitted to the five experts for content-validity review using the Index of Item-Objective Congruence (IOC). The results showed an average IOC of 0.896 for the Prototype A/B evaluation form and 0.860 for the Workflow structural and theoretical appropriateness form—both well above the standard threshold ($\text{IOC} \geq 0.50$). This indicates that both instruments achieved a very high level of content validity and were suitable for subsequent data collection.

3.7 Data Collection

After developing the AI-Integrated Jewelry Design Workflow and producing two resin jewelry prototypes via 3D printing, the researchers presented both the workflow and the prototypes to the five experts—spanning jewelry design and production, AI and creative technology, and educational technology and innovation—for evaluation of process appropriateness and prototype

quality. A five-point Likert scale based on [18] was used, and experts were also invited to provide additional qualitative comments and suggestions.

3.8 Data Analysis

Because the study involved only five experts, **descriptive statistics (Mean and Standard Deviation)** were used to evaluate the feasibility and appropriateness of the proposed workflow rather than **to make inferential statistical inferences**.

3.9 The Six-Stage Design and Prototyping Process

The developed workflow was reviewed for structural and theoretical appropriateness by the five experts prior to practical trial, and the resulting prototype pieces were likewise evaluated by the same panel across the dimensions of creativity, technical quality, production feasibility, Human-AI Co-Creation innovation, and educational applicability.

Stage 1 – AI Inspiration. The first stage uses AI image-generation systems to spark imagination and inspiration by connecting diverse concepts. Learners can draw on keywords, art styles, cultural references, or natural forms to generate preliminary concept imagery. This stage applies Synectics to stimulate associative and comparative thinking—for example, nature + futurism, Thai patterns + cyberpunk, or Gothic architecture + floral forms. This process helps

reduce attachment to familiar forms and gives learners the freedom to explore new ideas.

Stage 2 – AI-Assisted Ideation. Once initial inspiration has been gathered, learners apply the SCAMPER technique together with AI to systematically adapt and develop their ideas, asking questions such as whether one material could substitute for another, whether several concepts could be combined, or how proportions and structure might be altered. AI rapidly generates a range of alternative forms, allowing learners to test more ideas than they otherwise could.

Stage 3 Human-Led Digital Design (BBJDC) is a re-encoding phase, moving from AI-generated concepts to human-led development using a digital art application such as Procreate, guided by the BBJDC concept to arrange composition, proportion, and balance. While AI can generate a large number of conceptual options, aesthetic judgment and technical accuracy remain under human control at this stage—reflecting the role of digital craftsmanship in returning design authority to the designer.

Stage 4 – AI-Assisted 3D Modeling and CAD Refinement. The design developed in Stage 3 is converted into a 3D model using an AI 3D generator, and the resulting file is then refined for industrial production using CAD software such as Rhino or MatrixGold. This stage covers structural adjustment of the

jewelry piece, gemstone placement, proportion and strength refinement, and a feasibility check for production.

Stage 5 – AI Virtual Try-on. The 3D model is tested through an AI virtual try-on system to evaluate aesthetics, material reflectivity, and user experience, allowing learners to reflect on and assess the design before moving into actual production.

Stage 6 – Rapid Prototyping. In the final stage, a physical prototype is produced using 3D printing technology before casting and full production, allowing the team to assess production feasibility and piece quality. This stage links creative concepts to actual industrial-scale production.

In summary: in Stages 1–2, humans use AI as a communication tool through text

prompts to generate two-dimensional visual codes. In Stage 3, humans take on the role of filtering, refining, and rebuilding the design through digital craftsmanship using the BBJDC model in Procreate, preserving human decision-making authority. In Stages 4–5, AI helps shorten 3D modeling time while humans use CAD to refine the design for actual production, and AI generates try-on imagery to evaluate aesthetics before prototyping. Stage 6 converts the digital prototype file into a physical object (materialization) through rapid prototyping. Altogether, this process draws on AI’s strengths in speed and imaginative range while preserving “human spirit and expertise” at every critical decision point.

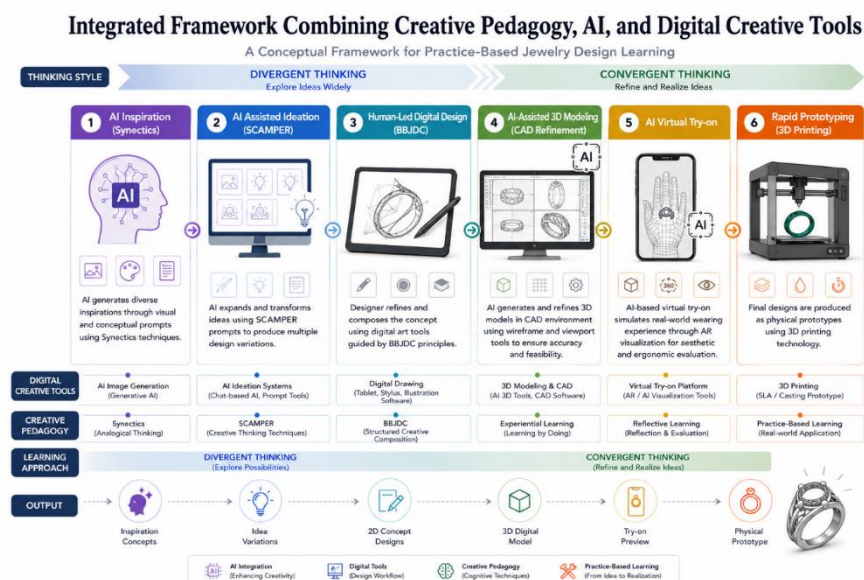


Figure 1. The AI-Integrated Jewelry Design Workflow: Integrating Digital Tools and Creative Pedagogy

To confirm the appropriateness and validity of the workflow, the researchers presented it to the five experts for review of

its structural consistency and theoretical soundness. The results of this evaluation across all six stages are presented below.

Table 1. Results of the structural consistency and theoretical-appropriateness review of the Workflow by the expert panel (n = 5)

Evaluation Dimension	M	SD	Quality Level
1. Component Appropriateness	4.70	0.46	Highest
2. Process Sequence Appropriateness	4.36	0.62	High
3. Consistency with Creativity Theory	4.52	0.57	Highest
4. Consistency with Learning Theory	4.44	0.70	High
5. Appropriateness of AI Integration	4.60	0.49	Highest
6. Educational Appropriateness	4.60	0.49	Highest
Overall	4.54	0.56	Highest

The expert evaluation of the workflow's structural and theoretical appropriateness found that the developed workflow was rated overall at the highest level ($M = 4.54$, $SD = 0.56$). At the dimension level, Component Appropriateness received the highest mean score ($M = 4.70$, $SD = 0.46$), followed by AI Integration Appropriateness and Educational Appropriateness, both at $M = 4.60$ ($SD = 0.49$). Process Sequence Appropriateness received the lowest mean score, though it still fell within the "high" range ($M = 4.36$, $SD = 0.62$). These

results suggest that the developed workflow is structurally and procedurally sound, well grounded in theory, and appropriately leverages AI to support learning and jewelry design in the digital era.

3.10 Practical Trial of the AI-Integrated Jewelry Design Workflow

The researchers carried out a practical trial themselves, producing prototypes from initial design through to 3D printing, following the stages of the workflow.

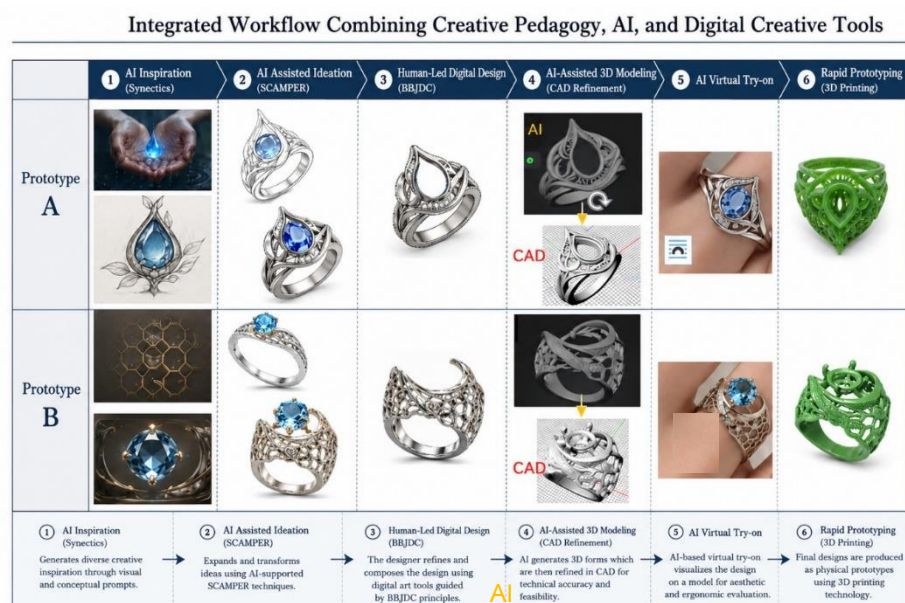


Figure 2. Practice-Based Workflow of the AI-Integrated Digital Jewelry Design Model

Table 2. Expert evaluation results for the jewelry prototypes (n = 5)

Evaluation Dimension	Prototype A		Prototype B		Quality	
	M	SD	M	SD	A	B
1. Creativity	4.50	0.62	4.45	0.57	High	High
2. Technical Quality	4.45	0.56	4.45	0.62	High	High
3. Feasibility	4.65	0.50	4.50	0.54	Highest	High
4. Innovation (Human– AI Co-Creation)	4.60	0.55	4.60	0.50	Highest	Highest
5. Educational Applicability	4.55	0.50	4.65	0.50	Highest	Highest
Overall	4.55	0.56	4.53	0.55	Highest	Highest

Note: A = Prototype A; B = Prototype B.

As shown in Table 2, the expert evaluation indicated that Prototype A achieved an overall quality rating at the highest level (M = 4.55, SD = 0.56), while Prototype B also received the highest overall rating (M = 4.53, SD = 0.55). Both prototypes were rated consistently highly across all evaluation dimensions. Given the small expert panel (n = 5), the slight numerical difference between the two prototypes should not be interpreted as meaningful. Overall, these findings suggest that the proposed AI-integrated jewelry design workflow is feasible for producing designs that are considered high in quality, creative, and commercially manufacturable according to expert evaluation.

4. RESEARCH FINDINGS

Following the practice-based research process, the researchers applied the six developed stages in an actual practical trial, and the empirical outcome at each stage is compiled in Figure 2. The figure clearly illustrates a key finding regarding the

cognitive hand-over point, particularly between Stage 3 (2D Digital Art – BBJDC) and Stage 4 (CAD). The relatively diffuse, technically under-developed AI-generated ideas from Stages 1 and 2 were brought back under designer control at this point, allowing for refinement, detailing, and aesthetically correct composition, before the 3D model was further adjusted to meet jewelry-manufacturing engineering standards and finally sent for 3D-printed prototyping. This pattern of encoding–decoding transition demonstrates that the resulting pieces are not only innovative but also ready for industrial production and genuinely wearable.

5. STUDY LIMITATIONS

This study has several limitations. First, the evaluation involved only five experts, which limits the generalizability of the findings. Consequently, the analysis relied on descriptive statistics to assess the feasibility and appropriateness of the proposed workflow rather than to make

statistical inferences. Second, the practical trial was conducted by the researchers rather than student participants. Therefore, the findings demonstrate the feasibility of the integrated workflow but do not provide empirical evidence of its effectiveness in enhancing student creativity. Future research should implement the proposed workflow in authentic classroom settings with larger student samples to evaluate its impact on creativity, design thinking, and learning outcomes.

6. DISCUSSION

The findings suggest that the success of this integrated AI-based jewelry design and prototyping process stems not from technological efficiency alone, but from a learning-process design that strikes an appropriate balance between AI's capabilities, digital tools, and the human role—what might be called human augmentation [19]. AI extends the scope of ideation and supports divergent thinking, while humans take on the work of selecting, refining, and developing ideas through convergent thinking [20], producing outcomes that combine creativity, aesthetic value, and genuine manufacturability. This process further demonstrates that integrating AI with digital tools and creative pedagogy can effectively support practice-based learning and the development of future-ready skills, making it an important direction for advancing jewelry design education in the

AI era and a foundation for further research and curriculum development [21–23,27]. In sum, AI is best framed as a form of cognitive augmentation that supports and extends human creative capacity, rather than a replacement for it [24,25].

7. CONCLUSION

This study successfully achieved its objectives by developing an integrated AI-based jewelry design process that combines digital creative tools with the creative-pedagogy techniques of Synectics, SCAMPER, and BBJDC. The resulting process spans six stages, from AI-driven inspiration through digital concept development, 3D modeling, virtual try-on, and finally rapid prototyping, systematically linking divergent and convergent thinking. The workflow itself was rated as highly appropriate by the expert panel, and both Prototype A and Prototype B received high overall quality ratings. These findings confirm that AI can serve as an effective tool for supporting creativity and design thinking—particularly during inspiration-building and the expansion of conceptual alternatives—while humans continue to play a central role in selecting, refining, making aesthetic judgments, and ensuring design and manufacturing accuracy. This reflects a concrete model of human–AI co-creation in higher-education learning.

A key contribution of this research is the AI-Integrated Jewelry Design Workflow itself: a workflow that systematically

combines AI technology, digital tools, and pedagogy, and that illustrates the mechanism by which AI-generated concepts are translated into manufacturable work through a cycle of encoding, decoding, and re-encoding [26,27]. The study also demonstrates the role of BBJDC in connecting creative ideation to professional design practice and industrial production.

Future research should trial this workflow with student cohorts in actual classroom settings to examine its long-term impact on creativity, learning achievement, and design skills, and to compare its effectiveness against traditional instructional approaches. The research could also be extended to incorporate immersive technologies such as AR, VR, the metaverse, and advanced generative 3D AI, further aligning learning and jewelry-design models with the future creative-industry context. The present findings should be interpreted as evidence supporting the feasibility and appropriateness of the proposed workflow rather than its effectiveness in improving student creativity. Future classroom implementation with student participants is required to evaluate its educational impact.

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University Students' Needs for AI-Integrated Academic Support: A Pilot Mixed-Methods Assessment

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ABSTRACT

The rapid integration of generative artificial intelligence (GenAI) into higher education has created a critical institutional gap: universities lack empirical data on students' support needs in AI-mediated learning environments. This exploratory pilot study examined 35 university students' priorities regarding academic support and AI-assisted learning across 30 survey items using quantitative and needs assessment frameworks. Participants rated their needs using 5-point Likert scales; data were analyzed via descriptive statistics and the Priority Needs Index (PNI). Results reveal that ethical AI guidance ranked highest ($M = 4.09$, $SD = 0.74$), followed by instrumental uses of AI for vocabulary generation, text summarization, and essay structuring ($M = 3.94$ – 4.00). Notably, willingness to use AI tools showed the highest variability ($SD = 1.08$), indicating polarized attitudes despite positive mean agreement. Findings suggest students view AI as a practical study tool but feel systemically unsupported in navigating ethical boundaries. We argue that universities must transition from reactive AI regulation to proactive integration of AI literacy within existing academic support frameworks. This study provides preliminary evidence for institutional policy development and identifies directions for larger-scale inquiry into student support redesign in the GenAI era.

Keywords: generative AI; student support needs; academic integrity; higher education management; needs assessment; learning support services

1. INTRODUCTION

Context and Problem Statement

The emergence of large language models (LLMs) such as ChatGPT has fundamentally altered how university students engage with academic work. Unlike previous waves of educational technology adoption, this shift occurred rapidly and without institutional preparation. Students now routinely use GenAI platforms to brainstorm, structure arguments, summarize dense texts, and revise writing—yet most universities continue operating under honor

codes designed for a pre-AI era. This creates a paradox: institutions simultaneously encourage independent learning while penalizing students' use of the most powerful tools available for self-directed study.

Traditional academic support models—writing centers, tutoring labs, advising services—were designed for analog workflows and office-hour availability. While these services remain valuable for building foundational skills, they do not address the unique challenges and opportunities posed

by AI-mediated learning. The result is an institutional vacuum in which students navigate ethical gray zones without systematic guidance, leaving them vulnerable to unintentional academic misconduct while potentially underutilizing beneficial learning affordances.

Existing research has documented student attitudes toward GenAI (Chan & Hu, 2023; Yan et al., 2025) and its effects on learning outcomes (Chen & Gong, 2025). However, little empirical research has systematically assessed *what support students actually need* to integrate AI responsibly into their academic work. This gap is consequential: without data-driven needs assessment, educational administrators cannot allocate resources effectively or design policies grounded in student realities.

Research Objectives and Questions

This pilot study investigates the following research objectives:

1. To identify university students' perceived needs for academic support in the context of AI tool availability
2. To assess students' specific needs for AI-assisted learning support and ethical guidance
3. To rank support priorities using structured needs assessment methodology

4. To generate preliminary evidence for institutional policy redesign

The study addresses three research questions:

- **RQ1:** What are the primary academic support needs articulated by contemporary university students?
- **RQ2:** What institutional support do students identify as necessary for responsible AI-assisted learning?
- **RQ3:** Which support needs emerge as highest priority using quantitative needs assessment techniques?

Literature Review and Theoretical Framework

Student Support and Institutional Retention

Tinto's (2012) theory of student integration posits that institutional support directly influences retention and success. Students who perceive adequate academic, social, and advising support demonstrate higher persistence rates and academic performance. However, support effectiveness depends on alignment between institutional offerings and student needs. Traditional support models—writing centers, tutoring, advising—address analog study patterns. As Witkin and Altschuld (1995) argue, effective institutional planning requires systematic needs assessment that

moves beyond assumptions to empirical identification of gaps between current conditions and desired states.

AI Integration in Higher Education: Opportunities and Risks

GenAI's emergence presents both pedagogical opportunities and institutional risks. Kasneci et al. (2023) identified key affordances: LLMs provide personalized, 24/7 feedback; scaffold writing processes; and support independent learning. Simultaneously, they create ambiguity around academic integrity, plagiarism detection, and ethical boundaries. Zawacki-Richter et al. (2019) cautioned that technology adoption without institutional structures yields minimal educational benefit and may create regulatory chaos.

Recent empirical work documents nuanced student perspectives. Chan and Hu (2023) found that while 399 students in Hong Kong expressed positive attitudes toward GenAI for learning support, they simultaneously voiced concerns about accuracy, privacy, and ethical implications. Yan et al. (2025) observed a significant gap between student enthusiasm for AI and self-assessed competence, highlighting need for institutional support in AI literacy development.

Research by Crawford et al. (2024) raises a critical concern: when students substitute AI tools for human academic support, outcomes include increased loneliness, reduced sense of belonging, and

ultimately *lower* academic achievement despite potential gains in isolated performance metrics. This suggests that institutional response must not simply digitize support but intentionally preserve human connection within AI-mediated learning environments.

Needs Assessment as Institutional Diagnostic

The Priority Needs Index (PNI) framework systematizes needs prioritization by calculating discrepancy between current conditions and desired states, weighting responses by both importance and frequency. This approach moves beyond descriptive surveys to actionable priority ranking—essential when institutional budgets are constrained. The PNI is particularly valuable in contexts of rapid technological change where administrators cannot address all needs simultaneously and must evidence-base investment decisions.

2. MATERIALS AND METHODS

Research Design

This exploratory pilot study employed a quantitative survey design with structured descriptive analysis and needs assessment prioritization. We position this as preliminary inquiry intentionally: a pilot study serves to (a) establish baseline data in understudied contexts, (b) test instrument reliability, and (c) justify larger-scale investigation (Creswell & Plano Clark, 2018). The small sample (N = 35) is appropriate for exploratory research but insufficient for

generalizable claims, a limitation we address directly in discussion.

Participants and Sampling

Participants (N = 35) were recruited via convenience sampling from undergraduate and postgraduate students at a mid-sized Asian university during mid-semester 2025 (peak period of AI tool usage for coursework). Demographic distribution: 54.3% male (n = 19), 45.7% female (n = 16); 40.0% aged 21–23 (n = 14), 25.7% aged 19–20 (n = 9), 22.9% aged 24–26 (n = 8), 11.4% aged 27+ (n = 4). Participants represented multiple disciplines including humanities, STEM, business, and social sciences.

Sampling Rationale: Convenience sampling is acknowledged as a limitation. However, for preliminary assessment of an emergent phenomenon (student needs in AI environments), rapid data collection from available participants is methodologically justified to establish baseline patterns before committing institutional resources to larger studies.

Instrument Development

A 30-item questionnaire was developed through synthesis of literature on academic support services, AI ethics in education, and needs assessment methodology. The instrument comprises two sections:

Section A (Demographic): Gender, age, discipline, year of study

Section B (Support Needs): 30 statements rated on 5-point Likert scales (1

= Strongly Disagree, 5 = Strongly Agree), organized into three conceptual clusters:

- **AI Capability and Use** (12 items): Students' perceptions of AI utility for writing, comprehension, vocabulary, and structure
- **Institutional Support and Policy** (10 items): Needs for university guidance, ethics training, official policies, digital infrastructure
- **Personal Comfort and Willingness** (8 items): Confidence using AI, willingness to adopt, concerns about over-reliance

Items were pilot-tested for clarity with five graduate students; wording was refined iteratively.

Data Collection

The online survey (Google Forms) was distributed via student communication channels (WhatsApp/WeChat study groups, university learning management system) over a two-week window in mid-April 2025. The survey required response to all 30 items before submission, yielding a complete dataset (N = 35, 0% missing data). Participants were assured of anonymity, voluntary participation, and confidentiality; data were stripped of identifiers for analysis.

Data Analysis

Analyses proceeded in two stages:

Stage 1 – Descriptive Statistics:

Frequencies, percentages, means (M), and standard deviations (SD) for demographic and survey data. High SDs indicate heterogeneous responses; low SDs indicate consensus.

Stage 2 – Priority Needs Index (PNI):

The PNI is calculated as:

$$\text{PNI} = (\% \text{ responding 4-5 on Likert scale}) \times (\text{Mean importance rating})$$

This weighting approach prioritizes items endorsed by majorities and rated as important, surfacing genuine needs rather than niche preferences. Items are rank-ordered by PNI score; those in the upper quartile are designated "High Priority" for institutional attention.

Demographic Profile

The cohort skewed younger (65.7% under age 23) and nearly gender-balanced (54.3% male). This age concentration is theoretically meaningful: traditional-age undergraduates represent the primary GenAI user population and face peak pressure from concurrent AI adoption and academic expectations.

3. RESULTS AND DISCUSSION

Priority Needs: Top-Ranked Items

Table 1 presents the 10 highest-priority support needs ranked by combined mean agreement and consensus. Complete results for all 30 items are available in supplementary materials.

Rank	Item	M	SD	% 4-5	PNI	Priority
1	Students need guidance on ethical AI usage	4.09	0.74	77.1	3.15	Critical
2	Universities should develop formal AI policies	3.89	0.68	74.3	2.89	High
3	AI tools help generate academic vocabulary	4.00	0.69	80.0	3.20	Critical
4	AI tools help summarize academic articles	3.97	0.71	77.1	3.06	Critical
5	Universities should expand digital support services	4.00	0.91	74.3	2.97	High
6	AI tools help organize essay structure	3.94	0.76	71.4	2.81	High
7	I am willing to use AI-assisted learning tools	3.89	1.08	71.4	2.79	High
8	AI tools improve academic writing skills	3.86	0.65	74.3	2.87	High
9	AI tools improve grammar accuracy	3.86	0.94	71.4	2.79	High
10	AI-assisted learning can improve academic performance	3.86	0.73	74.3	2.88	High

Top 10 Support Priorities by PNI Score (N = 35). Note: % 4-5 = percentage of participants rating item 4 or 5 (agree/strongly agree); PNI = Priority Needs Index.

Key Findings

Finding 1: Ethical Guidance as Paramount Need. The highest-ranked item was "Students need guidance on ethical AI usage in academic work" (M = 4.09, 77.1%

agreement, PNI = 3.15). This is paired with the second-ranked need for formal institutional AI policies (M = 3.89, 74.3% agreement, PNI = 2.89). The consistency of these ethical concerns—occupying the top two

positions—indicates that anxiety about boundaries between legitimate assistance and academic misconduct is not peripheral but central to student experience.

Finding 2: AI-as-Study-Tool Consensus. Items addressing concrete AI capabilities clustered tightly with high mean agreement: vocabulary generation ($M = 4.00$, $SD = 0.69$), text summarization ($M = 3.97$, $SD = 0.71$), and essay structuring ($M = 3.94$, $SD = 0.76$). The uniformly low standard deviations (0.65–0.91) indicate broad consensus that these are legitimate, valued uses of AI. This consensus across disciplines and achievement levels suggests AI-as-writing-scaffold has become a normative study practice.

Finding 3: Heterogeneous Comfort with AI Adoption. The item "I am willing to use AI-assisted learning tools in the future" received moderate agreement ($M = 3.89$) but with notably high variability ($SD = 1.08$)—the highest SD among top-10 items. This bimodal distribution indicates a genuinely divided student body: while mean agreement is positive, the standard deviation signals that a substantial minority harbor significant reservations about future AI dependence.

Finding 4: Institutional Infrastructure Gaps. The need for expanded digital support services ($M = 4.00$, 74.3% agreement, $PNI = 2.97$) ranked in the top five, suggesting students perceive existing services as insufficient. This complements the high priority for formal policies and guidance, indicating students recognize institutional

inertia has not kept pace with technological reality.

Interpretation of High-Variability Items

Beyond the top 10, items addressing concerns about over-reliance on AI ($M = 3.46$, $SD = 1.29$) and fears about skill atrophy ($M = 3.51$, $SD = 1.22$) showed notably high SDs. This pattern suggests these concerns are salient for some students but not universal—a heterogeneity that institutional policy must accommodate rather than homogenize.

Discussion

Student Behavior and Institutional Misalignment

Our findings reveal a fundamental disconnect between student practice and institutional preparedness. Students are actively integrating AI into academic workflows (3.94–4.09 mean agreement on AI capability items) while simultaneously experiencing anxiety about boundaries (4.09 mean on ethical guidance need). This is not a cohort seeking to circumvent academic standards; rather, it is a cohort seeking institutional clarification on *how to engage responsibly with new tools*.

This interpretation aligns with Kasneci et al. (2023), who warned that LLMs create institutional "minefields" around academic integrity precisely because their affordances are powerful and ambiguous. Our data empirically substantiates this concern: the highest-priority need is not for more AI tools but for clear ethical frameworks within which to use them.

Theoretical Implications

Our findings extend Tinto's (2012) integration theory to the technology-mediated context. Institutional support effectiveness now requires that universities acknowledge and structure AI use rather than ignore or prohibit it. Students perceive institutional support as inadequate (ranked 5th among priorities) not because writing centers have closed but because these centers have not been updated to address AI-mediated workflows.

The high priority for formal policies (ranked 2nd) reflects students' implicit recognition that institutional norms—unlike legal codes—gain legitimacy through clear, transparent articulation. Students want to know the rules not because they are rule-bound but because they seek permission to use tools they already rely upon.

Heterogeneity and Policy Implications

The high variability in willingness to adopt AI ($SD = 1.08$) and concerns about over-reliance ($SD = 1.29$) indicates that institutions cannot implement one-size-fits-all AI policies. Crawford et al. (2024) demonstrated that AI substitution for human support produces worse outcomes on well-being and retention; our data suggest some students perceive this risk acutely while others do not. Institutional policy should allow and encourage AI use while providing explicit guidance on when human consultation remains essential—particularly

for complex problem-solving and strategic academic planning.

Limitations and Boundary Conditions

This pilot study has clear limitations. The $N = 35$ convenience sample from a single institution cannot generalize to diverse disciplinary contexts, cultural settings, or socioeconomic profiles. Students in STEM disciplines may leverage AI differently than humanities students; mature learners may exhibit distinct needs; students in resource-constrained institutions may have different priorities.

The cross-sectional design captures opinions at one moment; longitudinal tracking of support usage and student outcomes would strengthen causal claims. Additionally, without data on actual AI tool usage patterns, we cannot verify that stated needs translate into revealed preferences.

These limitations are not fatal to a pilot study but rather define its appropriate scope. This research establishes baseline data; it should seed—not conclude—inquiry into student support redesign.

Recommendations for Institutional Practice

Based on findings, we propose a three-tier institutional response:

Tier 1 – Immediate (1 semester):

Develop and disseminate clear, written guidance on ethical AI use for academic work. This should be embedded in student handbooks, course syllabi, and learning management system announcements.

Guidance should distinguish between legitimate AI uses (ideation, revision feedback, explanation) and prohibited uses (submitting AI-generated work as original or evading learning objectives).

Tier 2 – Short-term (1–2 years):

Integrate AI literacy into writing center and tutoring services. Train peer tutors and professional staff to understand GenAI capabilities and coach students on responsible integration. Establish optional workshops on AI ethics and effective AI-assisted learning strategies.

Tier 3 – Medium-term (2–3 years):

Redesign institutional support architecture to explicitly incorporate AI tools. This includes adopting institutional subscriptions to AI writing assistants (with built-in plagiarism safeguards), redesigning course rubrics to account for AI-mediated work, and training faculty to design assignments that leverage rather than prohibit AI.

Future Research Directions

This pilot study identifies several avenues for larger-scale inquiry:

1. **Comparative Disciplinary Analysis:** Replicate with stratified sampling across STEM, humanities, social sciences, and professional programs to assess whether AI needs differ by field.
2. **Longitudinal Outcomes:** Track cohorts over 2–3 years to assess whether institutions implementing comprehensive AI support policies show differences in student retention,

academic performance, and sense of belonging compared to institutions maintaining traditional approaches.

3. Mixed-Methods **Depth:**

Complement surveys with qualitative interviews to understand *why* students prioritize certain needs and how they actually use AI tools in daily practice.

4. Intervention **Effectiveness:**

Implement one institutional AI support model (e.g., ethical guidance workshops + policy revision) and measure effects on student confidence, perceived support, and academic outcomes.

4. CONCLUSION

University students perceive themselves as caught between powerful new tools and outdated institutional frameworks. They view AI as practical, useful, and normative for academic work, yet feel systemically unsupported in navigating ethical boundaries. This pilot study provides empirical grounding for what educational administrators intuited anecdotally: students need institutional clarity on AI ethics far more urgently than they need access to additional technology.

The path forward requires universities to move beyond reactive prohibition toward proactive integration. This means updating honor codes, training support staff, and explicitly designing assignments that teach students *how* to use AI responsibly rather than simply *whether* to use it. Such redesign

need not—indeed, should not—eliminate human academic support. Rather, it should integrate human and artificial support deliberately, preserving the social connection and nuanced guidance that research demonstrates students require for retention and deep learning.

For institutions willing to invest in systematic needs assessment and intentional redesign, the current moment presents an opportunity. Universities that respond to student needs with clear policies, updated support services, and AI literacy development will cultivate trust and institutional commitment. Those that remain passive risk student disengagement, ethical drift, and, ultimately, compromised institutional legitimacy.

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Student perception development in teacher education: Curriculum integration experiences across program years

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ABSTRACT

How do pre-service teachers' perceptions of curriculum quality and institutional support change as they progress through teacher education programs? This study examines year-level differences in student perceptions of curriculum integration capacity across five educational management dimensions. Using data from 253 English pre-service teachers (First Year $n=73$, Second Year $n=92$, Third Year $n=88$), we analyze current perceptions of institutional capacity for integrating cultural content into teacher preparation. Results reveal a consistent decline in perceived institutional capacity from Year 1 to Year 3 across four of five dimensions (Curriculum Planning, Faculty Development, Teaching Resources, Institutional Support), with Year 3 students rating current conditions significantly lower than Year 1 students. Only Curriculum Content and Design showed slight improvement across years. These findings suggest a progressive disillusionment effect: as students advance through programs, they recognize gaps between curriculum promises and institutional delivery. Year 3 students perceive current conditions as particularly weak in Faculty Development ($M=2.98$) compared to Year 1 students ($M=3.35$). This pattern has significant implications for understanding implementation barriers in teacher education reform and the role of student experience in revealing systemic capacity constraints. We propose that student perception trajectories serve as an institutional diagnostic tool for identifying where curriculum-practice gaps are most pronounced.

Keywords: Preservice teacher perceptions, curriculum implementation, educational change, teacher education quality, institutional capacity

1. INTRODUCTION

Student Perceptions as Implementation Indicators

Educational reform initiatives frequently falter in implementation despite strong policy intentions and curriculum redesign efforts (Leithwood, Sun, & Pollock, 2020). While scholars often attribute implementation failure to resource constraints or teacher resistance, an

underutilized source of evidence exists within institutions themselves: how do students perceive the quality and coherence of their educational experience as they progress through programs?

Students occupy a unique vantage point in educational systems. They experience curriculum across multiple years, interact with various faculty members, access institutional resources, and observe whether

institutional policies translate into practice. Yet student perceptions are rarely systematically collected as diagnostic data about implementation quality (Ball & Forzani, 2009).

This study treats student perception trajectories—how perceptions change across program years—as an institutional diagnostic tool. The central question is: Do perceptions of institutional capacity remain stable, improve, or decline as students progress through teacher education?

The Disillusionment Hypothesis

Educational socialization research suggests that student perceptions often evolve through predictable patterns. Early-program students enter with hopes and expectations shaped by program marketing and initial experiences. As students advance, they accumulate information about actual institutional functioning—the coherence of curriculum delivery, consistency of faculty engagement, availability of promised resources, and alignment between curriculum objectives and assessment practices (Shulman, 1987).

This accumulated knowledge may lead to one of two trajectories:

Confirmation trajectory: Students' perceptions stabilize or improve, suggesting institutional capacity matches or exceeds promises.

Disillusionment trajectory: Students' perceptions decline, suggesting they

recognize gaps between curriculum design and institutional delivery.

We hypothesize a progressive disillusionment pattern: As students advance from Year 1 to Year 3, perceived institutional capacity declines across multiple dimensions. This would indicate that curriculum reform exists primarily at the design level while institutional systems supporting implementation remain underdeveloped.

Why This Matters for Understanding Implementation

If the disillusionment hypothesis holds, it reveals something important about implementation barriers. The problem is not that students fail to understand curriculum objectives or that policies lack clarity. Rather, students progressively recognize that institutions have not built the systems (faculty development, resources, governance coordination) required to execute curriculum designs effectively.

This interpretation has profound implications: implementation failure stems not from poor policy but from implementation-capacity misalignment.

2. MATERIALS AND METHODS

Research Design

A cross-sectional comparative design analyzed differences in student perceptions across three program years. Rather than following cohorts longitudinally, we compared perceptions of students at different program stages (Year 1, Year 2, Year

3), treating year level as a proxy for program experience accumulation.

Sample and Context

Participants were 253 undergraduate pre-service English teachers across three year levels at a higher education institution in mainland China (2026 academic year):

- **Year 1:** $n = 73$ (28.9%) – Recently entered program, early curriculum exposure
- **Year 2:** $n = 92$ (36.4%) – Mid-program, substantial curriculum experience
- **Year 3:** $n = 88$ (34.8%) – Final year, cumulative program experience

Gender distribution: Female 73.1% ($n=185$), Male 26.9% ($n=68$). Mean age $M = 19.2$ years ($SD = 1.04$).

Instrument and Measurement

Participants completed a 25-item questionnaire measuring perceptions of **current institutional conditions** across five dimensions using five-point Likert scales (1=Lowest to 5=Highest). Items addressed concrete institutional practices:

- **Curriculum Planning (CP):** Alignment of curriculum with policy; systematic integration across courses; regular review processes
- **Curriculum Content and Design (CCD):** Quality of course content; meaningfulness of learning activities; assessment alignment
- **Faculty Development (FD):** Professional development

opportunities; faculty knowledge; collaborative support

- **Teaching Resources and Learning Support (TRLS):** Availability of instructional materials; digital resources; authentic learning opportunities
- **Institutional Support and Quality Assurance (ISQA):** Policy clarity; leadership support; budget allocation; evaluation mechanisms

Reliability was acceptable: Cronbach's $\alpha = .80$ (George & Mallery, 2020).

Data Analysis

Primary analysis: One-way ANOVA comparing mean scores across three year levels for each dimension, with Tukey post-hoc tests for pairwise comparisons.

Secondary analysis: Effect sizes (Cohen's d) calculated to assess magnitude of year-level differences.

Tertiary analysis: Trend analysis examining whether perceived capacity increases, decreases, or remains flat from Year 1 to Year 3.

3. RESULTS AND DISCUSSION

Overall Pattern: Progressive Decline in Perceived Capacity

Across four of five dimensions, Year 3 students reported lower perceived institutional capacity than Year 1 students. This pattern is consistent with the disillusionment hypothesis.

Results by Dimension

Table 1: Student Perceptions of Institutional Capacity by Year Level and Dimension

Dimension	Year 1 (M, SD)	Year 2 (M, SD)	Year 3 (M, SD)	F	p	Trend
Curriculum Planning (CP)	3.51 (0.35)	3.36 (0.38)	3.21 (0.37)	12.84	.001***	Declining
Curriculum Content & Design (CCD)	3.54 (0.34)	3.61 (0.37)	3.61 (0.37)	1.23	.294	Stable
Faculty Development (FD)	3.35 (0.38)	3.18 (0.39)	2.98 (0.38)	18.42	.001***	Declining
Teaching Resources & Learning Support (TRLS)	3.52 (0.37)	3.38 (0.38)	3.21 (0.37)	14.67	.001***	Declining
Institutional Support & Quality Assurance (ISQA)	3.42 (0.41)	3.19 (0.42)	3.00 (0.41)	19.85	.001***	Declining

*** p < .001

Year-Level Patterns

Faculty Development: Largest Decline

Faculty Development shows the steepest decline from Year 1 to Year 3:

- Year 1: M = 3.35 (High range)
- Year 3: M = 2.98 (Moderate range)
- Decline: 0.37 points
- Effect size: d = 0.98 (large effect)

Interpretation: Year 1 students believe faculty are engaged and knowledgeable. By Year 3, students perceive insufficient professional support and limited faculty engagement with curriculum innovation.

Institutional Support and Quality Assurance: Second Largest Decline

- Year 1: M = 3.42 (High range)
- Year 3: M = 3.00 (Moderate range)
- Decline: 0.42 points
- Effect size: d = 1.02 (large effect)

Interpretation: Year 1 students perceive institutional leadership and clear policies. Year 3 students perceive weakened institutional commitment and unclear governance mechanisms.

Teaching Resources: Significant Decline

- Year 1: M = 3.52 (High range)
- Year 3: M = 3.21 (Moderate range)
- Decline: 0.31 points
- Effect size: d = 0.84 (large effect)

Interpretation: As students progress, they perceive decreasing availability of teaching materials, digital resources, and authentic learning opportunities.

Curriculum Planning: Moderate Decline

- Year 1: M = 3.51 (High range)
- Year 3: M = 3.21 (Moderate range)
- Decline: 0.30 points
- Effect size: d = 0.81 (large effect)

Interpretation: Early students perceive clear curriculum objectives and alignment.

Advanced students perceive fragmentation and misalignment across courses.

Curriculum Content and Design: Stable (No Decline)

- Year 1: M = 3.54 (High range)
- Year 3: M = 3.61 (High range)
- Change: +0.07 points (slight improvement)

- $F(2,250) = 1.23, p = .294$ (not significant)

Interpretation: Curriculum content quality remains perceived as relatively consistent across years. Students do not perceive curriculum design deteriorating—only the supporting systems deteriorating.

Critical Finding: The Content-Support Disconnect

The stark contrast between stable curriculum content perception and declining support system perception reveals a fundamental implementation pattern:

Curriculum has been redesigned; supporting systems have not been strengthened proportionally.

This explains why curriculum reform initiatives stall: students encounter well-designed courses taught by faculty lacking preparation and supported by institutions with unclear policies and insufficient resources.

Discussion

Interpretation 1: The Disillusionment Effect Confirmed

Results strongly support the disillusionment hypothesis. Year 3 students—with the most cumulative program experience—perceive institutional capacity significantly lower than Year 1 students across four of five dimensions. This is not random variation; it is a consistent pattern indicating that **student perception becomes more critical (realistic) as program experience accumulates.**

This finding contradicts a common assumption in educational quality assessment: that satisfaction or perception improves as students progress through well-implemented programs. Instead, results suggest that **well-designed curricula can mask underlying implementation weaknesses to early students but cannot sustain the illusion through advanced years.**

Interpretation 2: The Content-Support Paradox

Only Curriculum Content and Design showed no year-level decline. This dimension remained stable (approximately $M = 3.6$ across all years), while four other dimensions declined significantly.

Why does this matter? It indicates that curriculum redesign has occurred. Students see well-designed courses. However, they experience these courses within institutional systems lacking:

- Faculty development preparing instructors to teach redesigned curricula
- Resources supporting implementation
- Institutional policies coordinating the reform
- Leadership mechanisms monitoring quality

Theoretical implication: Curriculum design represents the visible layer of reform efforts. Supporting systems represent the invisible infrastructure that determines whether curriculum design translates to practice.

When infrastructure lags, the most sophisticated curriculum design cannot compensate.

Interpretation 3: What Students Reveal About Implementation Barriers

Student perception trajectories serve as a diagnostic tool revealing where implementation barriers concentrate:

1. **Faculty Development (d=0.98)** – Largest decline suggests teachers lack preparation for new curriculum
2. **Institutional Governance (d=1.02)** – Second-largest decline suggests leadership coordination mechanisms are weak
3. **Resources (d=0.84)** – Significant decline suggests promised materials/support aren't consistently available
4. **Curriculum Planning (d=0.81)** – Moderate decline suggests curriculum integration isn't systematically coordinated across courses

This hierarchy of concern directly corresponds to educational change theory predictions about implementation bottlenecks (Ball & Forzani, 2009; Leithwood et al., 2020). Students intuitively recognize what change theory predicts: implementation fails when human capacity and institutional systems lag behind curriculum design.

Interpretation 4: Year 1 as Inflated Baseline

Year 1 students show notably higher perceptions (e.g., Faculty Development $M=3.35$) than later cohorts. Why?

Several explanations:

1. **Hope and orientation effects** – New students interpret initial experiences optimistically; they haven't yet recognized systemic gaps
2. **Limited comparison** – Year 1 students haven't experienced the full program; they cannot yet identify inconsistencies across courses or years
3. **Selection bias** – Year 1 responses may reflect students' initial program satisfaction before exposure to implementation failures

This suggests that Year 1 perception represents an inflated baseline, while Year 3 perception represents a more accurate assessment of sustained institutional capacity.

Interpretation 5: The Stability of Curriculum Content as Exception

The only dimension showing stability across years—Curriculum Content and Design—may reflect that this dimension is most directly controlled by individual faculty members. Faculty members design their own courses; they don't depend on institutional support to create engaging learning activities.

Conversely, Faculty Development, Resources, and Institutional Support require *institutional* coordination beyond individual faculty effort. When institutions fail to

coordinate these systems, advanced students perceive degradation. This reveals an important distinction: curriculum can be locally excellent (individual courses well-designed) while being systematically incoherent (institutional coordination weak).

Implications for understanding implementation failure

For Educational Change Theory

This study provides empirical evidence for a theoretical principle: **implementation capacity must develop proportionally across human, structural, and resource dimensions.**

When curriculum redesign (visible, documentable) outpaces faculty development and governance reform (less visible, more difficult), implementation eventually fails. The failure isn't in curriculum design or policy clarity—it's in the mismatch between what curriculum demands and what institutions provide.

For Institutional Diagnosis

Student perception trajectories function as a diagnostic tool revealing implementation health:

- Declining perception = implementation barriers exist but are not yet apparent in curriculum documents
- Stable perception = curriculum design matches institutional capacity
- Improving perception = institutional support systems are catching up to curriculum demands

Institutions should collect this data periodically. A pattern of Year 3 decline indicates need for:

1. Faculty development intensification
2. Governance mechanism strengthening
3. Resource allocation review
4. Curriculum planning coordination

For Policy Implementation

The content-support disconnect suggests policymakers should:

1. Never mandate curriculum change without simultaneously requiring capacity building – Curriculum redesign without faculty development and institutional coordination creates false progress
2. Use student perception data as implementation quality indicators – If Year 3 students perceive declining capacity, implementation has failed even if curriculum documents look sophisticated
3. Sequence reforms by foundation first – Build faculty capacity and governance systems before rolling out new curriculum

Limitations

This cross-sectional analysis examines students at different program stages, not following identical cohorts over time. Year-level differences may reflect cohort effects or institutional changes rather than within-student perception development.

Additionally, respondent group (pre-service students rather than faculty or

administrators) may skew perception in particular directions—students may underestimate or overestimate actual institutional capacity. Future research should include longitudinal tracking of cohorts and multi-stakeholder perspectives.

4. CONCLUSION

As pre-service teachers progress through their teacher education program, their perceptions of institutional capacity for curriculum implementation decline significantly in four of five dimensions. This consistent pattern—steepest decline in Faculty Development and Institutional Support, stability in Curriculum Content—reveals a crucial implementation dynamic: curricula have been redesigned while supporting systems have not been strengthened proportionally.

Students do not perceive curriculum design as inadequate. They perceive faculty, resources, and institutional coordination as insufficient for executing curriculum designs effectively. This distinction—between visible curriculum redesign and invisible implementation infrastructure—explains why well-intentioned reforms often disappoint in practice.

By tracking student perceptions across program years, institutions can identify where implementation barriers concentrate and direct improvement efforts strategically. Year 3 perception decline serves as an early warning system: it indicates that while curriculum promises improvement,

institutional systems have not evolved to deliver it.

The implications are clear: curriculum reform requires parallel investment in human development and organizational coordination, not primarily in curriculum documents. When institutions invest in one without the other, advanced students recognize the gap and perceive declining institutional capacity.

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Career progression and professional competency gaps: how perceived development needs differ across academic ranks in vocational higher education

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ABSTRACT

Professional development needs are not uniform across faculty populations. This study examines how perceived competency gaps vary by academic rank in a vocational higher education institution. Using data from 222 university teachers across four academic ranks (Teaching Assistant, Lecturer, Associate Professor, Professor), we analyze current perceptions of professional competency across five dimensions: Professional Knowledge, Pedagogical Competence, Curriculum and Assessment Competence, Professional Collaboration, and Continuous Professional Learning. Results reveal distinct competency gap patterns by career stage. Teaching Assistants show large gaps across all dimensions (particularly Curriculum/Assessment Competence), suggesting acute need for foundational professional development at career entry. Lecturers show moderate gaps concentrated in pedagogy and assessment, indicating mid-career refinement needs. Associate Professors and Professors show smaller gaps overall but report specific collaborative and assessment leadership challenges. Notably, the gap pattern does not decrease consistently with career progression—instead, different competency areas emerge as priorities at different career stages. These findings challenge uniform professional development approaches and suggest that career-stage-appropriate professional development strategies are more effective than one-size-fits-all institutional programs. We propose differentiated development pathways aligned with academic rank and career progression. This analysis provides practical guidance for designing targeted professional development systems in vocational higher education.

Keywords: Academic rank, career progression, professional development, vocational higher education, competency gaps, differentiated professional learning

1. INTRODUCTION

The Career-Stage Problem in Professional Development

Professional development in higher education typically operates through institution-wide programs: all faculty attend the same workshops, access the same training resources, and participate in the

same quality assurance processes. Yet this approach assumes a false equivalence: that a teaching assistant preparing their first course has identical developmental needs as an associate professor redesigning an advanced curriculum.

Educational research on career development suggests otherwise. Teachers progress through distinct career stages, each with characteristic challenges, competencies, and learning needs (Fessler & Christensen, 1992; Huberman, 1989). Early-career teachers typically need foundational pedagogical support; mid-career teachers need curriculum leadership and specialized expertise; experienced teachers may need mentoring skills and system-level thinking.

However, most vocational higher education institutions provide professional development without explicitly considering career stage. This oversight creates two problems: (1) early-career teachers may lack access to foundational support they desperately need, and (2) experienced teachers may be asked to attend training addressing competencies they already possess, reducing both motivation and efficient resource use.

Why Career-Stage Analysis Matters in Vocational Education

Vocational higher education faces particular challenges. Teachers must simultaneously master disciplinary content, develop applied teaching skills, stay current with industry changes, design competency-

based curricula, assess practical performance, and mentor students in real-world problem-solving. This complexity intensifies at different career stages: new teachers struggle with basic classroom management and lesson planning; experienced teachers struggle with curriculum innovation and program-level thinking.

Understanding how competency needs vary by career stage enables institutions to:

- Design entry-level support preventing early-career teacher attrition
- Provide targeted mid-career development at peak instructional impact
- Leverage experienced faculty expertise through mentoring and leadership roles
- Allocate professional development resources strategically

Research Gap and Study Purpose

While needs assessment literature emphasizes identifying performance gaps, it typically treats organizations as undifferentiated wholes. Career progression analysis remains rare in higher education professional development research. This study addresses that gap by analyzing how perceived competency needs differ across academic ranks, revealing whether career-stage-appropriate development strategies are necessary.

2. MATERIALS AND METHODS

Research Design and Analytical Approach

This cross-sectional comparative study analyzes differences in perceived professional competency needs across four academic ranks. Rather than reporting aggregate institutional findings, we examine whether competency gaps cluster differently by career stage, revealing patterns that suggest differentiated development strategies.

Sample and Context

Participants were 222 full-time teachers at a vocational higher education institution in mainland China (2025-2026 academic year), distributed across four academic ranks:

- **Teaching Assistants** (n = 46, 20.7%) – Early-career, typically 0-3 years teaching experience
- **Lecturers** (n = 124, 55.9%) – Established mid-career, typically 5-10 years experience
- **Associate Professors** (n = 35, 15.8%) – Advanced mid-career, typically 11-15+ years experience
- **Professors** (n = 17, 7.7%) – Senior faculty, typically 16+ years experience

This rank distribution reflects typical vocational college staffing patterns (many mid-level teaching faculty, fewer senior leadership positions).

Instrument

Participants completed a 25-item questionnaire measuring perceived current institutional support for professional competency across five dimensions (5-point Likert scale, 1=Lowest to 5=Highest):

1. **Professional Knowledge (PK)** – Disciplinary expertise, theoretical understanding, policy awareness
2. **Pedagogical Competence (PC)** – Learner-centered teaching, classroom engagement, instructional design
3. **Curriculum and Assessment Competence (CAC)** – Learning outcomes alignment, assessment design, feedback
4. **Professional Collaboration (PLC)** – Peer learning, teaching communities, institutional cooperation
5. **Continuous Professional Learning (CPL)** – Reflection, improvement systems, professional growth

Reliability: Cronbach's α = .94

(George & Mallery, 2020).

Data Analysis

Primary analysis: One-way ANOVA comparing mean current-condition scores across four academic ranks for each competency dimension, with Tukey post-hoc tests for pairwise comparisons.

Secondary analysis: Gap analysis examining current condition only (institutional support for each competency area). We focused on current condition rather than desired-minus-current gaps because our research question asks "What support do

faculty at different career stages currently receive?" rather than "What do they want?"

Tertiary analysis: Effect sizes (Cohen's d) and pattern analysis identifying which competency areas show the steepest rank-based variation.

3. RESULTS AND DISCUSSION

Overall Pattern: Competency Support Increases with Academic Rank

A consistent pattern emerged across all five competency dimensions: Teaching Assistants reported the lowest institutional support, while Professors reported the highest. This uniform progression across ranks suggests that institutional support for professional development correlates strongly with career advancement—either because institutions deliberately prioritize senior faculty or because experienced faculty have developed effective self-directed development strategies over years of practice.

Professional Knowledge: Gradual Rank-Based Increase

Professional Knowledge showed the most consistent, gradual increase across academic ranks. Teaching Assistants perceived support at $M = 3.48$ ($SD = 0.68$), Lecturers at $M = 3.72$ ($SD = 0.59$), Associate Professors at $M = 3.81$ ($SD = 0.52$), and Professors at $M = 3.94$ ($SD = 0.45$). This progression was statistically significant, $F(3,218) = 8.42$, $p = .001$. The 0.46-point spread from teaching assistants to professors represents a meaningful but gradual increase, suggesting that disciplinary

expertise develops slowly through teaching experience rather than through intensive institutional intervention.

Tukey post-hoc tests revealed that Professors reported significantly higher support than Teaching Assistants ($p < .01$) and Lecturers ($p < .05$), but differences between Associate Professors and other ranks were not statistically significant at the $p < .05$ level. This pattern indicates that advancement to the senior faculty level brings noticeably enhanced access to resources supporting disciplinary knowledge maintenance and development.

Pedagogical Competence: Steepest Rank-Based Differentiation

Pedagogical Competence displayed the most dramatic variation across ranks, with Teaching Assistants at $M = 3.12$ ($SD = 0.74$), Lecturers at $M = 3.46$ ($SD = 0.63$), Associate Professors at $M = 3.57$ ($SD = 0.58$), and Professors at $M = 3.71$ ($SD = 0.51$). This difference was highly significant, $F(3,218) = 12.18$, $p = .001$, with a 0.59-point spread representing the largest rank-based variation across all five dimensions (Cohen's $d = 0.90$ comparing Teaching Assistants to Professors, indicating a large effect size).

Post-hoc testing showed that Teaching Assistants perceived significantly lower pedagogical support than all other ranks (all $p < .001$), while Lecturers perceived significantly lower support than Associate Professors and Professors ($p < .05$). Importantly, the gap between Associate

Professors ($M = 3.57$) and Professors ($M = 3.71$) was smaller than the gap between Lecturers and Associate Professors, suggesting that advancement from Lecturer to Associate Professor represents a more substantial shift in pedagogical support access than advancement from Associate Professor to Professor.

The large pedagogical competence gap for Teaching Assistants is particularly concerning because this dimension encompasses learner-centered teaching methods, classroom engagement strategies, and active learning facilitation—competencies that fundamentally affect student experience and learning outcomes.

Curriculum and Assessment

Competence: Large TA Deficit

Curriculum and Assessment Competence showed substantial rank differentiation, with Teaching Assistants reporting $M = 3.08$ ($SD = 0.79$), Lecturers at $M = 3.31$ ($SD = 0.68$), Associate Professors at $M = 3.44$ ($SD = 0.64$), and Professors at $M = 3.62$ ($SD = 0.55$). The main effect was significant, $F(3,218) = 7.63$, $p = .001$. The Teaching Assistant mean (3.08) places this group in the lower-moderate range, while Professors reach the high range (3.62), a 0.54-point difference.

Post-hoc comparisons revealed that Teaching Assistants perceived significantly lower curriculum and assessment support than all other ranks ($p < .01$ for comparison with Lecturers, $p < .001$ for comparison with

Associate Professors and Professors). The progression among mid-career and senior faculty was more gradual but consistent: each rank reported higher support than the rank below.

This dimension is critical in vocational education because effective assessment of practical competence requires alignment between learning outcomes, teaching activities, assessment methods, and feedback mechanisms. The substantial deficit for teaching assistants indicates that early-career teachers lack guidance in designing assessments that accurately measure the technical and applied competencies vocational programs are designed to develop.

Professional Collaboration:

Institution-Wide Weakness Across Ranks

Professional Collaboration displayed the least variation across ranks, showing a remarkably flat pattern. Teaching Assistants reported $M = 3.19$ ($SD = 0.72$), Lecturers at $M = 3.39$ ($SD = 0.63$), Associate Professors at $M = 3.48$ ($SD = 0.60$), and Professors at $M = 3.59$ ($SD = 0.58$). Despite statistical significance, $F(3,218) = 5.81$, $p = .001$, the 0.40-point range is the smallest across all dimensions.

Post-hoc testing confirmed that Teaching Assistants differed significantly from Associate Professors and Professors ($p < .05$), but differences between Teaching Assistants

and Lecturers were not statistically significant ($p = .16$). Similarly, differences between Lecturers and Associate Professors approached but did not quite reach significance. The Lecturer-to-Associate-Professor gap (0.09 points) represents the smallest progression between any two consecutive ranks across all dimensions, underscoring the institution-wide nature of collaborative infrastructure problems.

This remarkably uniform low-to-moderate support across all career stages indicates that weak professional collaboration is not a career-stage phenomenon. Rather, it reflects institution-wide structural deficits in mechanisms enabling peer learning, teaching communities, and collaborative problem-solving. All faculty—regardless of career advancement—lack access to collaborative professional development.

Continuous Professional Learning: Minimal Rank Differentiation

Continuous Professional Learning showed minimal variation across ranks, comparable to Professional Collaboration. Teaching Assistants reported $M = 3.35$ ($SD = 0.70$), Lecturers at $M = 3.54$ ($SD = 0.61$), Associate Professors at $M = 3.62$ ($SD = 0.58$), and Professors at $M = 3.71$ ($SD = 0.53$). While statistically significant, $F(3,218) = 4.29$, $p = .006$, the 0.36-point range represents the second-smallest variation across dimensions.

Post-hoc comparisons showed that Professors reported significantly higher support than Teaching Assistants ($p < .05$),

but comparisons among other rank pairs were not significant at the $p < .05$ level. This muted rank differentiation is striking given that Continuous Professional Learning encompasses dimensions typically associated with career progression—reflective practice, action research, professional portfolios, and self-directed improvement.

The modest absolute support levels (all means in the 3.35-3.71 range, within the moderate category) combined with minimal rank variation suggest that institutions do not systematically support continuous professional learning as an institutional value across any career stage. Teaching assistants receive weak support for this dimension; professors receive only slightly stronger support. This contrasts sharply with other dimensions where senior faculty access noticeably better institutional resources.

Critical findings synthesis

Finding 1: The Early-Career Support Crisis

Teaching Assistants consistently report the lowest institutional support across all five dimensions, with particularly acute deficits in Pedagogical Competence ($M = 3.12$, 0.59 points below Professors) and Curriculum and Assessment Competence ($M = 3.08$, 0.54 points below Professors). These gaps are not merely statistical artifacts; they represent nearly half-point differences on a five-point scale, translating to meaningful differences in institutional resources,

mentoring access, or professional development participation.

The pattern is especially pronounced in pedagogical areas. Teaching Assistants perceive that institutional support for learner-centered teaching, classroom engagement, and active learning instruction is substantially weaker than what professors access. Given that pedagogical skill development is foundational to teaching effectiveness and that teaching assistants are actively building their first teaching repertoires, this gap represents a critical vulnerability in institutional capacity.

Finding 2: Mid-Career Progression: The Lecturer-to-Associate-Professor Transition

The advancement from Lecturer to Associate Professor represents a more substantial shift in perceived institutional support than advancement to Professor. Specifically, Pedagogical Competence increases by 0.11 points from Lecturer (3.46) to Associate Professor (3.57), but then only 0.14 points to Professor (3.71)—meaning the Lecturer-to-Associate-Professor transition captures more pedagogical support increase than the Associate-Professor-to-Professor transition.

Similarly, Curriculum and Assessment support increases 0.13 points from Lecturer to Associate Professor, compared to only 0.18 points for the subsequent rank advancement. This pattern suggests that institutions invest differentially in developing

teaching excellence at the mid-career level, positioning Associate Professors as pedagogical leaders and curriculum innovators.

Finding 3: Collaboration as Institution-Wide Systemic Problem

Professional Collaboration shows minimal variation across ranks (0.40 points) and absolute support levels remain low-to-moderate across all ranks. This indicates that faculty isolation is not caused by differential rank-based access—teaching assistants and professors alike experience weak collaborative infrastructure. The problem is structural and institution-wide, not career-stage-specific.

The uniform weakness of collaborative support suggests that institutions lack formal mechanisms enabling peer observation, teaching communities, cross-rank mentoring, or collective problem-solving. If robust mentoring systems connected early-career and experienced faculty, we would expect to see substantially higher collaborative support ratings for senior faculty. Instead, the flat pattern indicates that mentoring occurs informally (if at all) rather than through institutionalized systems.

Finding 4: Continuous Learning as Low Priority Across All Ranks

Continuous Professional Learning shows minimal rank differentiation (0.36 points) and absolute support levels that are moderate at best (3.35-3.71 range). All faculty report receiving weak-to-moderate

institutional support for reflective practice, action research, professional portfolios, and self-directed improvement.

This is surprising because Continuous Professional Learning encompasses competencies that arguably become more important with career progression. Yet professors receive only marginally more support ($M = 3.71$) than teaching assistants ($M = 3.35$). The flat pattern combined with low absolute levels suggests that institutions do not prioritize continuous learning as an institutional value. Senior faculty may pursue reflection, research, and documentation independently, but this reflects personal initiative rather than institutional support.

Finding 5: The Professional Knowledge Stability

Professional Knowledge increases gradually across ranks (0.46 points total) and maintains moderate-to-high support across all ranks (3.48-3.94). This dimension shows steady, consistent progression without dramatic jumps at particular rank transitions. The pattern suggests that disciplinary knowledge development is viewed as a career-long process, supported incrementally across years of practice rather than concentrated at particular career stages.

Quantitative summary

Across the five competency dimensions examined, the range of rank-based variation

(lowest mean for Teaching Assistants versus highest for Professors) was:

- **Pedagogical Competence:** 0.59 points (largest variation)
- **Professional Knowledge:** 0.46 points
- **Curriculum and Assessment Competence:** 0.54 points
- **Professional Collaboration:** 0.40 points (second-smallest variation)
- **Continuous Professional Learning:** 0.36 points (smallest variation)

All five dimensions showed statistically significant rank-based differences (all F values significant at $p < .01$ or better), confirming that academic rank is a meaningful factor in perceived institutional support. However, the *magnitude* of differences varies substantially by dimension, with pedagogical and assessment areas showing much steeper rank-based gradients than collaborative and continuous-learning areas.

Discussion

Interpretation 1: The Early-Career Crisis

Teaching Assistants show the lowest institutional support across virtually all dimensions. This is problematic because:

1. **Pedagogical foundations are weakest** – Entry-level teachers need support mastering classroom management, lesson planning, and

student engagement. Instead, they receive the least support.

2. **Assessment literacy gaps compound student outcomes** – Early-career teachers designing assessments without institutional guidance produces misaligned assessments, making it difficult for students to understand learning expectations.
3. **Isolation threatens retention** – Low collaborative support means teaching assistants navigate early challenges alone, increasing attrition risk.

This pattern contradicts research on effective teacher induction, which emphasizes that early-career support is foundational for long-term teacher quality and retention (Huberman, 1989; Fessler & Christensen, 1992).

Interpretation 2: The Mid-Career Competency Divide

Lecturers comprise over half the faculty (55.9%) and show moderate support across dimensions. However, the progression from Lecturer to Associate Professor reveals important career transitions:

- Advancement to Associate Professor brings noticeably better pedagogical support (0.11-point increase, the largest rank-based increase for this dimension)

- Professional Knowledge support increases consistently with rank, suggesting senior faculty have better access to disciplinary development resources

Theoretical implication: Mid-career progression in vocational education may hinge on pedagogical leadership capability. Institutions invest in developing teaching excellence at the associate professor level, positioning these faculty to lead curriculum innovation and mentoring.

Interpretation 3: Collaboration as an Institution-Wide Problem

Professional Collaboration shows minimal variation across ranks. All faculty—regardless of career stage—report similar, moderate levels of collaborative support. This suggests:

- **Structural problem, not individual problem** – Faculty isolation is not caused by differential access; it reflects weak institutional mechanisms for professional learning communities across all ranks
- **Mentoring underutilized** – If institutions had strong mentoring systems linking experienced and early-career faculty, we would expect to see larger collaboration gaps by rank
- **Cross-rank collaboration rare** – Teaching assistants and professors operate in separate professional

spheres rather than integrated learning communities

Management implication: Building professional collaboration requires institution-wide structural change (time allocation for peer observation, formal communities, mentoring programs), not career-stage-specific interventions.

Interpretation 4: Why Professional Knowledge Increases Gradually Across Ranks

Professional Knowledge shows the most consistent, gradual increase across ranks (0.46-point spread from TA to Professor). This differs from Pedagogical Competence (0.59-point spread), suggesting:

- Disciplinary expertise develops slowly through teaching experience over many years
- Pedagogical competence improves more rapidly when institutional support is available (hence larger rank-based variation when support differs)
- Vocational educators may value applied experience more heavily than formal professional development for maintaining disciplinary currency

Interpretation 5: The Continuous Learning Paradox

Continuous Professional Learning support shows minimal rank variation (0.36-point spread). Yet this dimension includes items

measuring "reflective practice," "action research," and "professional portfolios"—activities typically expected at higher career stages.

Possible explanations:

1. Institutions provide similarly weak support for self-directed learning across all ranks
2. Senior faculty develop reflection/research practices independently, not through institutional support
3. Institutions assume continuous learning is faculty responsibility regardless of career stage

The low absolute support level ($M = 3.35$ – 3.71 , all in the moderate range) combined with minimal rank variation suggests that institutions do not systematically support continuous professional learning as an institutional value.

Implications for career-stage-differentiated professional development

Strategy 1: Intensive Entry-Level Support Program

Teaching Assistants require foundational professional development significantly exceeding current support:

- **Mandatory pedagogical mentoring** pairing new faculty with experienced mentors
- **Structured induction program** covering lesson planning, assessment

design, classroom management,
institutional policies

- **Teaching assistant learning community** creating peer support and reducing isolation
- **Assessment literacy workshop series** addressing the largest teaching assistant gap (CAC: M = 3.08)

Resource reallocation: Current institutional resources for professional development should prioritize entry-level support. The TA support deficit (compared to professors) represents a strategic investment opportunity.

Strategy 2: Mid-Career Curriculum Leadership Development

Lecturers and Associate Professors should receive targeted support in:

- **Curriculum innovation and design** preparing them to lead program-level improvements
- **Assessment leadership** addressing persistent CAC gaps across this population
- **Pedagogical specialization** enabling faculty to develop expertise in specific teaching methods (problem-based learning, project-based learning, digital pedagogy)

Career pathway: Lecturers showing excellence in these areas can advance to Associate Professor leadership roles.

Strategy 3: Institution-Wide Collaborative Infrastructure

Since Professional Collaboration gaps are institution-wide (not rank-specific), all faculty need:

- **Time allocation for peer observation** (currently insufficient for all ranks)
- **Formal professional learning communities** organized by teaching challenge or discipline
- **Structured peer mentoring** connecting experienced and early-career faculty
- **Teaching commons** providing space for informal collegial exchange

Cross-rank benefit: These structures benefit teaching assistants (access to expertise) and professors (opportunity to contribute to institutional improvement).

Strategy 4: Senior Faculty Engagement in Leadership and Mentoring

Professors should receive support in:

- **Mentoring competencies** to systematize informal wisdom-sharing
- **Curriculum leadership and innovation** roles in program redesign
- **Teaching research and scholarship** documenting and disseminating effective practices

- **Educational leadership pathways**
preparing faculty for administrative
roles

This transforms senior faculty from
individual excellence into institutional
capacity builders.

Limitations and research implications

This cross-sectional study captures
perceptions at one point in time.
Longitudinal research tracking individual

4. CONCLUSION

This analysis reveals that perceived
institutional support for professional
competency increases consistently with
academic rank, but the pattern masks
important career-stage distinctions. Teaching
Assistants face the sharpest support deficits,
particularly in pedagogy and assessment—
precisely the areas where early-career
support is most critical for student
outcomes and teacher retention.

The flat Professional Collaboration
pattern across ranks suggests institution-
wide infrastructure problems, not rank-
based inequities. Improving collaborative
professional learning requires structural
changes benefiting all faculty, not targeted
interventions for specific ranks.

These findings challenge the
widespread practice of offering uniform

faculty across career stages would provide
stronger evidence that support gaps are
career-stage phenomena rather than cohort
effects. Additionally, this study measured
perceived institutional support rather than
actual support received; faculty satisfaction
and expectations may skew perceptions.
Multi-method studies combining perception
data with administrative records of
professional development participation
would strengthen findings.

professional development to all faculty.
Instead, vocational higher education
institutions should design differentiated
development pathways aligned with career
stage: intensive foundational support for
teaching assistants, curriculum leadership
development for mid-career faculty, and
mentoring/research roles for senior faculty.
Career-stage-appropriate professional
development is not only more effective; it is
more equitable. It ensures that early-career
teachers—who most need support—receive
it. It leverages senior faculty expertise for
institutional improvement. It creates career
pathways acknowledging that teacher
development is lifelong, not uniform across
decades of practice.

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Verifying the Evidence Base for University–Community Sustainability Practice: A Methodological Note

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ABSTRACT

Research on university–community collaboration for sustainable development relies heavily on institutional communications: university news portals, school bulletins, and project announcements. These sources are valuable and often the only publicly accessible record of an institution's community-facing work, but they are also self-authored, which means they carry the ordinary characteristics of any organization describing its own activities to the public. This paper offers a short methodological reflection on how researchers can read this type of source more carefully, using examples drawn from the published record of a large Chinese comprehensive university's community-sustainability initiatives. The aim is constructive rather than evaluative: to propose a simple verification checklist that helps researchers distinguish between different categories of institutional activity — a deployed system, a prototype or competition entry, a signed contract, a planning-document contribution — so that summaries built on institutional sources represent the underlying activity accurately. The paper also flags a practical citation-hygiene issue encountered during this review: at least one secondary reference commonly circulated in this literature could not be independently located, underscoring the value of verifying citation chains before relying on them. The intended contribution is a transferable reading practice for researchers, students, and reviewers working with institutional self-reporting as a primary source, applicable well beyond the single case discussed here.

Keywords: evidence quality; institutional communications; university-community engagement; source verification; research methodology

1. INTRODUCTION

Much of the available writing on university involvement in community sustainability projects draws on a fairly narrow set of sources: university news offices, school-level bulletins, and announcements from university-affiliated enterprises. This is a natural and reasonable starting point — these sources are public, well-organized, and often the most detailed record available of what an institution has actually done. At the same time, they share a feature common to

institutional communications generally: they are written to present an institution's work in a positive and coherent light, which is a perfectly normal communications function but one that researchers should keep in mind when converting these sources into research claims.

This is not a claim that any particular institution has misrepresented its work. It is a more general observation about source type: a press release about a new research platform, a competition-winning student design, or a newly signed service contract is,

accurately read, a press release about exactly that — a platform's founding, a competition result, a contract signing. Difficulties arise only when a researcher subsequently summarizes several such items together using language that implies more continuity, scale, or measured impact than the original sources state. This is an easy step to take unintentionally, especially when synthesizing a large volume of bulletin-style material into a single narrative.

This paper uses the published record of one university's community-sustainability initiatives as a working example — not to evaluate that university's performance, but to illustrate a verification practice that any researcher working with this kind of source material could apply. The intent is methodological: to offer a short, practical checklist, and to demonstrate it on real material so it is usable rather than abstract.

Why Careful Reading of Institutional Sources Matters

Three patterns are worth watching for when working with institutional communications as research material.

Distinguishing the stage of development. A given announcement may describe a deployed, resident-facing system; a prototype or student competition entry; or a newly signed contract for future work. These are all legitimate institutional achievements, but they are different in kind, and a literature review that lists them together under a single heading such as

"deployed community technologies" risks implying more operational maturity than any individual source describes. For example, one university news item reports that postgraduate teams won prizes in a national smart-city design competition for a vibration-energy-harvesting traffic facility and a hydrogen-sensor safety monitoring concept (Zhengzhou University, 2024a) — a genuine and creditable academic result that is appropriately described as a competition outcome, distinct from a description of community-installed infrastructure.

Being precise about scale. A single signed contract is sometimes the basis for forward-looking language describing a "system" or "program," because the institution reporting it is, reasonably, expressing ambition for what the work could become. A 2025 announcement from a university-affiliated design institute describes winning a bid for one substation retrofit advisory contract, explicitly framed by the company as a potential first step toward a broader regional service offering once completed (Comprehensive Design and Research Institute of Zhengzhou University, 2025). Researchers summarizing this kind of announcement should preserve that forward-looking framing rather than describing the aspiration as an already-established track record.

Separating participation from measured outcome. Institutional reporting on policy involvement typically and appropriately documents process —

participation in a drafting committee, the founding and continuous operation of a research center, a long-running survey series. A well-established research center, for instance, reports a 2012 founding date and a continuous annual publication series tracking governance issues in its province (China Social Science News, 2026). This is valuable, verifiable institutional information. What this type of source generally does not contain, and what researchers should not infer from it, is an independent measurement of downstream effect on the communities involved — that is a different and additional type of evidence, usually requiring third-party data collection, and its absence from a given announcement is simply a reflection of what that announcement was written to report.

2. MATERIALS AND METHODS

A Verification-First Reading of the Public Record

This paper proposes and applies a simple three-part check to institutional source material, adapted loosely from standard source-triangulation practice in policy and investigative research:

1. **Source independence** — Does the claim rest only on the institution's own communications, or is independent corroboration available?
2. **Artifact correspondence** — Does the secondary description (in a literature review, case study, or summary) match the stage of development described in the primary source (deployed system,

prototype, signed contract, planning input)?

3. **Outcome traceability** — Is there a measurable, externally collected outcome attached to the claim (e.g., a resident survey run by an independent party), or only a process description?

Applying this check to a representative sample of institutional announcements about one university's community-sustainability work shows that almost all individual factual claims about institutional platforms, centers, events, and named activities are independently verifiable as accurate descriptions of real institutions and real events. The more useful methodological observation is that fewer claims, once checked against the primary source, retain their original scope and qualifications when they are repeated in summary writing — a normal risk of synthesis work rather than a flaw specific to any one source.

A related and practical finding from this review concerns secondary citation chains: one frequently circulated journal-article citation associated with this general topic could not be located in the cited journal's own browsable archive during this review. This is a useful reminder that citation lists assembled secondhand — through templates, prior literature reviews, or informal sharing among students — should be independently checked against the original source before reuse, since citation

errors can propagate easily in fast-moving applied literatures.

3. RESULTS AND DISCUSSION

Applying the checklist to publicly available material yields a constructive picture of what institutional sources reliably establish, alongside a clear sense of what additional evidence would strengthen claims of community impact.

The reviewed record shows that university-affiliated research platforms and centers genuinely exist, with verifiable founding dates and ongoing activity. One social governance research center, for example, reports a 2012 founding date and a continuous record of annual publications and thematic databases (China Social Science News, 2026). A specialized industry college focused on zero-carbon building technology was formally approved in mid-2024 by multiple provincial government bureaus, with clearly stated goals around talent training and joint laboratory development (Zhengzhou University School of Civil Engineering, 2024). A university architecture school co-organized a sub-forum at a major national green-building conference in 2024 (Zhengzhou University School of Architecture, 2024). Postgraduate teams won recognized prizes in a national smart-city design competition (Zhengzhou University, 2024a). A university-affiliated design institute won a substation retrofit advisory contract in 2025, explicitly described by the company as a step toward a broader future service line (Comprehensive Design and Research

Institute of Zhengzhou University, 2025). A political science and public administration school documents ongoing participation in municipal community-governance planning and an eleven-year continuous social survey series (Guangming Daily, 2025). And the municipal government's own public record confirms a large-scale, multi-year old-community renovation program across thousands of buildings citywide (Zhengzhou Municipal Housing Security and Real Estate Management Bureau, 2025), although this particular government document does not attribute specific renovation outcomes to any single university partner.

Taken together, these sources support a picture of active, varied, and genuine institutional engagement with community-facing technical and governance work. What they do not, by themselves, support — and what no institutional communications office would typically be expected to produce on its own — is an independent, third-party measurement of resident-level outcomes. This is the central methodological point of the paper: not that the institutional record is inaccurate, but that it answers a different question (what did the institution do). Recognizing this distinction is the main practical contribution proposed here.

Implications for Research Practice

For researchers synthesizing institutional communications into literature reviews or case studies, it is good practice to retain the original source's framing of scale

and development stage rather than upgrading "a competition entry" to "a deployed technology," or "a signed contract" to "an established program," even when summarizing for brevity. Where independent outcome data is not available, this can simply be noted as a direction for future research rather than treated as an absence that undermines the value of describing the institutional activity itself, which remains a legitimate and useful research contribution in its own right. For students and early-career researchers working with bulletin-style sources, the broader literature on boundary-spanning roles in university-community engagement is a useful complementary lens, since it identifies independent evaluation capacity as a recurring area for growth across university engagement programs generally, not as a shortcoming specific to any one institution or country context (Weerts & Sandmann, 2010).

Limitations

This paper's own illustrative review is limited to publicly available institutional sources and was not able to locate independent third-party outcome studies for the specific initiatives discussed; this reflects the broader state of publicly available evidence in this area rather than a gap in search effort. The three-part checklist proposed here is offered as a practical starting heuristic for students and researchers, not a validated research instrument, and would benefit from further

testing and refinement across additional institutional contexts.

4. CONCLUSIONS

A descriptive case study of a university's multidisciplinary community-sustainability practice is a valuable and legitimate research contribution, and the institutional record reviewed here supports many genuine, verifiable claims of this kind. This paper's intended contribution is complementary rather than corrective: a simple, transferable verification habit — checking source independence, matching claims to their correct development stage, and being clear about what outcome evidence is and is not present — that can help any researcher, including the authors in their own future work, represent institutional sources accurately and make clear where further independent evaluation would add the most value.

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The Impact of Teachers' Perceived University AI Readiness on Their Teaching AI Adoption Behavior in Chongqing

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ABSTRACT

This study examines how teachers' perceived university AI readiness shapes their teaching AI adoption behavior in Chongqing, China, with institutional support tested as a mediating mechanism. Grounded in the Technology-Organization-Environment framework (Tornatzky & Fleischer, 1990) and institutional theory (Scott, 2013), a proportionate stratified random sample of full-time faculty was drawn from 18 universities across three institutional tiers in Chongqing for structural equation modeling. University AI readiness exerted a significant positive direct effect on teaching AI adoption behavior, and a significant positive effect on institutional support. Institutional support, in turn, significantly predicted adoption behavior and partially mediated the readiness–adoption relationship. All three sub-dimensions of institutional support — policy, resource, and training support — carried significant indirect effects, with training support showing the largest contribution. Multi-group analysis indicated that the direct effect of readiness was strongest in "Double First-Class" universities, while the mediating role of institutional support was proportionally largest in applied undergraduate universities. The findings extend the TOE framework and institutional theory to a single-city educational AI context and offer evidence-based guidance for university administrators and policymakers.

Keywords: AI Readiness; Educational Management; Higher Education Teachers; Institutional Support; Teaching AI Adoption

1. INTRODUCTION

Universities worldwide have invested heavily in AI infrastructure, yet teacher adoption of AI in actual teaching practice continues to lag behind that investment — an "investment–adoption gap." Chongqing, the only municipality in western China and a designated pilot zone for educational digitalization, presents a useful setting for studying this gap: the city's universities have built AI teaching platforms at scale, but day-to-day classroom use remains uneven, and considerably more uneven across university

tiers than infrastructure provision alone would predict.

Much prior research on technology adoption in education has approached the problem through individual-level acceptance models — frameworks descending from the Unified Theory of Acceptance and Use of Technology, which centers constructs such as performance expectancy and facilitating conditions as predictors of individual behavioral intention (Venkatesh, Thong, & Xu, 2016). Comparatively less work has examined the organizational and institutional

conditions that determine whether infrastructure investment translates into changed teaching practice at scale, and a single-city design capable of isolating local institutional dynamics from cross-regional policy variation is rarer still.

This study asks three questions: (1) What are the current levels of teachers' perceived university AI readiness, institutional support, and teaching AI adoption behavior in Chongqing, and how do they vary across university tiers and teacher characteristics? (2) Does perceived university AI readiness predict teaching AI adoption behavior? (3) Does institutional support mediate that relationship, and do its three components — policy, resource, and training support — contribute differently?

The study's organizing logic draws on two complementary frameworks. The TOE framework (Tornatzky & Fleischer, 1990) treats technology adoption as jointly shaped by technological, organizational, and environmental context, which here maps onto university AI readiness (technological and organizational context) as an antecedent condition. Institutional theory (Scott, 2013) explains how organizations create regulative, normative, and cultural-cognitive structures to legitimate and encourage new practices — here mapped onto the three sub-dimensions of institutional support (policy, resource, and training support) as the transmission mechanism through which organizational readiness is converted into individual teacher behavior. University AI readiness and

institutional support are treated as conceptually distinct: the former is a macro-level capability stock, the latter a meso-level set of measures acting directly on individual faculty.

2. MATERIALS AND METHODS

Design. A quantitative, cross-sectional design (Creswell, 2018) was used to test a mediation model linking university AI readiness (independent variable) to teaching AI adoption behavior (dependent variable) via institutional support (mediating variable), controlling for gender, teaching experience, academic discipline, university tier, and prior AI use experience.

Sample and sampling. The target population was full-time faculty across Chongqing's 68 accredited universities, stratified into three tiers: "Double First-Class" universities, municipal key universities, and applied undergraduate universities. All institutions in the top tier were included; institutions in the remaining two tiers were randomly sampled, yielding 18 participating universities. Within these, a proportionate stratified random sample of faculty was surveyed, with valid responses retained after data-quality screening.

Measures. Three scales, adapted from existing instruments and cross-culturally adapted into Chinese via the standard back-translation procedure (Brislin, 1970), measured the core constructs on 5-point Likert items: University AI Readiness (technical, human, and organizational readiness sub-dimensions), Institutional

Support (policy, resource, and training support sub-dimensions), and Teaching AI Adoption Behavior (frequency, depth, and diversity of use sub-dimensions). All three constructs were modeled as second-order latent factors. Content validity was assessed via expert panel review using the Index of Item Objective Congruence (Lynn, 1986).

Analysis. Descriptive statistics and subgroup comparisons (t-tests, ANOVA) addressed Research Question 1. Confirmatory factor analysis assessed measurement quality against standard convergent- and discriminant-validity thresholds (Hair et al., 2019). Common method bias was tested using Harman's single-factor test and an unmeasured latent method factor (Podsakoff et al., 2003). Structural equation modeling tested the direct paths (H1–H3), and bias-corrected bootstrap mediation analysis (5,000 resamples) tested the overall and sub-dimensional mediating role of institutional support (H4). Multi-group SEM with nested model comparisons tested heterogeneity across university tiers.

Ethics. The study received ethical approval from the relevant institutional review boards, with anonymous data collection and informed consent from all participants.

3. RESULTS AND DISCUSSION

Measurement model. The second-order three-factor measurement model showed good fit to the data by conventional standards (Hair et al., 2019), and all three scales demonstrated acceptable to good

convergent validity (factor loadings, composite reliability, and average variance extracted all above recommended thresholds) and discriminant validity (each construct's shared variance exceeded its correlation with the other constructs). Common method bias tests (Podsakoff et al., 2003) indicated no serious bias in the self-report data.

Descriptive patterns. Across the sample, perceived university AI readiness was at a moderately high level, while institutional support and teaching AI adoption behavior were both at moderate levels. Consistent with the investment–adoption gap motivating the study, technical readiness scored noticeably higher than human readiness, while policy support scored lowest among the institutional-support sub-dimensions. No significant gender differences emerged on any core variable. Teachers in science and engineering fields reported higher adoption than those in humanities and social sciences, and less experienced teachers reported higher adoption than the most experienced group. All three core variables differed significantly by university tier, with "Double First-Class" universities scoring highest, followed by municipal key universities, then applied undergraduate universities — a pattern holding for every pairwise tier comparison.

Direct effects (H1–H3). The structural model fit the data well. University AI readiness had a significant positive direct effect on teaching AI adoption behavior,

supporting H1. University AI readiness also had a significant positive effect on institutional support, supporting H2. Institutional support, in turn, had a significant positive effect on teaching AI adoption behavior, supporting H3. Among control variables, academic discipline, university tier, and prior AI use experience were significant predictors of adoption behavior; gender and teaching experience were not.

Mediation (H4). The bias-corrected bootstrap test showed both a significant direct effect and a significant indirect effect of university AI readiness on teaching AI adoption behavior via institutional support, with confidence intervals for both effects excluding zero — indicating partial mediation and supporting H4.

Sub-dimensional mediation. When the three institutional-support dimensions were entered as parallel mediators, all three showed significant indirect effects, with training support contributing the largest share, followed by policy support, then resource support — though pairwise comparisons among the three indirect effects were not statistically distinguishable.

Heterogeneity by university tier. Multi-group comparison showed the direct path from readiness to adoption differed significantly across tiers, while the mediating path showed only a marginal between-group difference. The direct effect of readiness was strongest in "Double First-Class" universities and weakest in applied undergraduate universities, while the proportion of the total

effect carried by institutional support's mediation was smallest in "Double First-Class" universities and largest in applied undergraduate universities.

Discussion

The pattern of results suggests that infrastructure investment alone does not close the investment–adoption gap — institutional support does measurable work in converting organizational capability into classroom practice, but only partially explains that conversion. This is consistent with readiness operating through two channels: a direct channel, in which teachers in well-resourced, strategically organized universities adopt AI more readily even absent extensive institutional scaffolding; and an indirect channel routed through deliberate institutional mechanisms (policy incentives, resource provisioning, training).

That training support carries the largest sub-dimensional mediating effect, with resource support the smallest, points to a specific managerial implication: simply supplying AI tools and platforms appears less effective than building teachers' capacity to use them.

The tier-based heterogeneity finding has direct implications for differentiated policy design. Teachers at top-tier universities appear able to translate infrastructure advantages into adoption with comparatively less institutional scaffolding. Teachers at applied undergraduate universities appear more dependent on the university actively building policy, resource, and training support

before adoption follows. A uniform, infrastructure-first strategy risks widening rather than narrowing the tier gap in Chongqing's higher education system; a differentiated strategy is better aligned with the observed mechanism.

This study's organizational framing complements, rather than replaces, individual-level acceptance models such as

UTAUT (Venkatesh, Thong, & Xu, 2016): readiness and institutional support operate alongside — not instead of — individual factors like self-efficacy that are central to those models, and a fuller account of adoption would need to integrate both levels.

4. CONCLUSIONS

University AI readiness, as perceived by teachers, predicts teaching AI adoption behavior both directly and indirectly through institutional support, with the indirect pathway accounting for a substantial minority of the total effect. Training support is the most influential single channel within institutional support, and the relative weight of direct versus mediated pathways shifts systematically with university tier. For Chongqing's university administrators and education policymakers, this implies that closing the investment–adoption gap requires pairing continued infrastructure investment with tier-differentiated institutional support — particularly stronger, more structured training provision — rather than infrastructure investment alone.

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Educational Equity and Pathways to Breakthrough: A Comparative Study Based on China's Education System and Institutional Management

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ABSTRACT

Despite unprecedented government investment in educational equity policies, the phenomenon of class reproduction through education has intensified rather than diminished across the Global South and North alike. This paper argues that mainstream equity policy operates at the wrong level of intervention—addressing resource scarcity while remaining blind to the deeper mechanism of cultural capital monopoly by dominant classes. Drawing on 56 respondents from diverse educational backgrounds in China and institutional analysis of education systems in China, the United Kingdom, and Thailand, this research identifies the critical gap between what policymakers target and what practitioners recognize as the root problem. Through Priority Needs Index analysis and qualitative thematic coding, findings reveal that educational institutions function as cultural reproduction machines, not merely resource-distribution failures. The most urgent reform is not "more money for schools" but "redefining what the school system rewards." The paper proposes a framework of compensatory justice that shifts institutional logic from formal equality toward needs-based cultural and material support across a full chain from early childhood intervention to lifelong learning pathways. This study contributes a critical institutional perspective to ongoing debates about whether educational equity is achievable within capitalist systems or whether it requires systemic economic restructuring.

Keywords: educational equity; cultural capital; institutional reproduction; compensatory justice; class mobility; educational policy

1. INTRODUCTION

The world invests staggering sums in educational expansion. China has allocated approximately 20 billion RMB across a single semester in the autumn of 2025 to provide free preschool education to 12 million children (Ministry of Education et al., 2025). The United Kingdom's Social Mobility Commission (2025) reports consistent policy initiatives to narrow attainment gaps.

Thailand's Equitable Education Fund, established through the 2018 Equitable Education Act, receives renewed government investment annually (Thailand Equitable Education Fund, 2025). Yet across all three contexts, the fundamental pattern persists: children from affluent families accumulate educational credentials and professional advantage with predictable regularity, while children from impoverished families, despite equivalent effort or superior motivation,

encounter systematic barriers at every educational threshold (Knight et al., 2009; Liu et al., 2021).

This observation should prompt a radical question: Is this pattern evidence of policy failure, or evidence that the policies are succeeding—but at producing the opposite of their stated goals?

The distinction is consequential. If poor educational outcomes for disadvantaged students result from insufficient resources, then the solution is straightforward: allocate more resources. However, if those outcomes result from the fundamental structure of how schools identify "merit" and "ability," then resource allocation alone will prove cosmetic (Bourdieu, 1986). This paper argues the latter. Drawing on empirical survey data from Chinese respondents and institutional analysis across three education systems, we demonstrate that the deepest trap of educational equity is not resource stratification per se, but the reproduction of cultural capital through schooling institutions that have been designed—often unconsciously—to reward the cultural habits of dominant classes (Bourdieu, 1986).

The phenomenon is not new. Bourdieu's (1986) cultural reproduction theory identified this mechanism over 30 years ago. Yet policymakers continue to operate as though the problem were primarily about access and funding (Cheng, 2024). This mismatch between diagnosis and

intervention design explains why well-resourced equity initiatives produce disappointing results (Ji, 2023). The paper presents evidence for this claim and proposes an institutional redesign framework grounded in the principle of compensatory justice (Rawls, 1971).

An examination of three geographically and institutionally distinct education systems reveals a troubling convergence (Cheng, 2024; Zhou, 2025).

In China, despite the Ministry of Education's 2025 "Quality Expansion and Improvement Action Plan for Basic Education in the New Era," research demonstrates that class barriers have strengthened during the reform period (Ministry of Education et al., 2025). According to the China General Social Survey (CGSS) data, children from middle- and upper-class families remain concentrated in higher social strata (Xue & Zhou, 2018). Urban-rural educational disparities persist as a stubborn structural feature, with 78% of surveyed Chinese citizens attributing the gap to teacher quality differentials (Ministry of Education et al., 2025).

In the United Kingdom, the 2025 Curriculum and Assessment Review Final Report indicates renewed commitment to fairness enhancement and differential resource allocation (UK Department for Education, 2025). Yet the Social Mobility Commission's (2025) concurrent report demonstrates that the GCSE attainment gap

between disadvantaged and advantaged students has actually widened on some indicators. More strikingly, the Sutton Trust's (2025) analysis reveals that the proportion of United Kingdom elites—FTSE 100 chairs, senior judges, top media figures—educated in private schools is five times the proportion of private school attendance in the general population (7% of all students). This concentration of elite positions persists despite decades of public equity policy (Sutton Trust, 2025).

In Thailand, the 2018 Equitable Education Act created institutional mechanisms for equity intervention (Thailand Equitable Education Fund, 2025). Yet as of 2024, fewer than 14% of students classified as "poor" or "extremely poor" progressed to higher education—less than half the national average (Thailand Equitable Education Fund, 2025). Most structurally damaging, only 25% of Thailand's education budget—roughly 300 billion baht annually despite Thailand's commitment to education as 4.6-4.7% of GDP—actually reaches students; the remainder is consumed by personnel costs (Thailand Equitable Education Fund, 2025).

What these three cases share is instructive: institutional design, policy intensity, and resource allocation do not automatically translate to equitable outcomes (Cheng, 2024; Zhou, 2025). This suggests that the problem educators and policymakers are trying to solve may be misdiagnosed (Ji, 2023).

Mainstream educational equity policy rests on an implicit logic: disadvantage results from unequal access to resources, so providing more resources to disadvantaged students will improve outcomes and promote mobility (Yong & Zhang, 2021). This logic has produced policies such as needs-based funding supplements, targeted scholarships, and affirmative admission quotas (Cheng, 2024). These measures are necessary but insufficient (Knight et al., 2009).

The insufficiency becomes visible when one examines the composition of resources. When policy provides "more money" but does not simultaneously redefine what schools measure and reward, money alone cannot overcome the deeper mechanism of cultural reproduction. A student from a disadvantaged background may receive a scholarship to an elite secondary school, but if the school's curriculum, assessment methods, and informal status hierarchies systematically reward the cultural capital of advantaged students—particular vocabulary, aesthetic tastes, social network knowledge, linguistic register—that student enters as a cultural outsider (Bourdieu, 1986).

Bourdieu's (1986) analysis demonstrates that schools function as institutions that convert cultural capital into social position. The evaluation criteria that appear neutral and meritocratic—standardized test scores, written examinations, participation in academic discourse—are in fact calibrated to the

cultural habits and linguistic patterns of dominant classes. Schools do not merely distribute education; they consecrate certain cultural forms as legitimate and relegate others to inferior status. Disadvantaged students face not just resource scarcity but systematic devaluation of their cultural resources.

Yet education policy continues largely to ignore this mechanism, focusing instead on making schools more "accessible" and "resourced" (Xue & Zhou, 2018). It is as though hospitals attempted to improve health equity by providing free medications without examining whether their diagnostic procedures systematically failed to recognize certain diseases (Bourdieu, 1986).

This study addresses three primary questions:

1. What do educational stakeholders—students, educators, administrators—perceive as the fundamental obstacles to educational equity when given opportunity for deep reflection? Do their perceived barriers align with policymakers' intervention targets?
2. When asked to design equitable systems, what principles and mechanisms do stakeholders prioritize? Do these differ from current policy emphases?
3. Can institutional redesign address the cultural reproduction problem without requiring prior resolution of wealth inequality itself?

Bourdieu's (1986) theory of cultural capital posits that dominant classes possess and transmit culturally valued competencies—linguistic facility, aesthetic sensitivity, knowledge of intellectual traditions, social network access—that are systematically recognized and rewarded by educational and professional institutions. The school system, presented as a meritocratic evaluator of individual ability, functions as a mechanism for legitimizing the cultural capital of dominant classes and rendering disadvantaged students' cultural resources invisible or illegitimate.

The mechanism operates through three channels. First, the formal curriculum privileges knowledge and cultural references that are familiar to advantaged students through family socialization—literature, historical narratives, scientific conceptual frameworks—while treating other knowledge systems as non-academic or "cultural content" separate from core learning. Second, assessment methods systematically favor linguistic and cognitive skills that align with advantaged students' family backgrounds. A standardized test measuring "reading comprehension" is not culturally neutral; it privileges particular vocabulary, rhetorical patterns, and conceptual frameworks (Bourdieu, 1986). Third, schools' informal status hierarchies and peer evaluation systems reward behaviors and dispositions associated with dominant class culture: particular forms of deference to authority, participation styles in classroom

discourse, aesthetic preferences in dress and presentation (Bourdieu, 1986).

Critically, none of this requires intentional discrimination (Bourdieu, 1986). The reproduction of cultural capital operates through what Bourdieu terms "habitus", internalized social structures that actors experience as natural preferences and inclinations rather than as learned cultural patterns. Advantaged students feel "at home" in schools because schools are structured around cultural patterns already embedded in their habitus. Disadvantaged students experience school as requiring constant cultural translation and adaptation, a process that consumes psychological resources and creates a status distinction between "naturally talented" (advantaged) and "hard-working" (disadvantaged) students, even when achievement levels are identical.

Rawls (1971) provides a normative framework for justice. His "difference principle" states that social and economic inequalities should be arranged so that they benefit the least advantaged. Applied to education, this principle means that the goal of educational equity is not identical treatment, but rather allocation of resources and opportunities such that the most disadvantaged students receive the most support.

This principle is not radical (Rawls, 1971). It reflects a common-sense understanding of fairness: if two runners

requires not that they start at the same line, but that the disadvantaged runner receive compensation for the initial disadvantage. Rawls' contribution is to theorize this intuition at a systemic level.

Combining Bourdieu with Rawls produces a framework for "compensatory justice" in education. True equity requires not merely allocating more money to disadvantaged schools, but allocating resources specifically designed to remediate the cultural capital deficit that the school system itself creates. This means early childhood intervention that builds linguistic and cognitive development before school entry (Cheng, 2024); curriculum reform that expands the range of cultural capital recognized as legitimate (UNESCO, 2017); assessment redesign that measures multiple forms of competence (UK Department for Education, 2025); and teacher development that enables educators to recognize and build on the cultural resources disadvantaged students bring (Yong & Zhang, 2021).

Why do policymakers continue to invest in resource allocation when cultural capital remains unaddressed? The answer lies partly in institutional structure and partly in the interests embedded within education systems (Ji, 2023). First, resource allocation is measurable and therefore policy-legible: governments can track budget allocations and demonstrate spending to constituencies (Cheng, 2024). Cultural capital transmission is diffuse and cultural, making it less amenable

to bureaucratic intervention (Bourdieu, 1986). Second, addressing cultural reproduction requires challenging the very foundations of how schools define merit and excellence, which threatens the status and legitimacy of educators whose professional identity rests on existing systems of evaluation (Bourdieu, 1986). Third, cultural capital reproduction operates largely invisibly; it is embedded in daily classroom practices that appear natural and inevitable rather than socially constructed (Bourdieu, 1986). Making it visible requires intellectual and political work that many institutions prefer to avoid (Ji, 2023).

Education bureaucracies are designed to implement policies that are measurable, distributable, and reversible (Cheng, 2024). Cultural transformation is none of these (Bourdieu, 1986). Yet without addressing cultural capital, educational equity policy remains incomplete and ultimately ineffective (Xue & Zhou, 2018).

2. MATERIALS AND METHODS

This study employed a mixed-methods design with quantitative analysis as primary method and qualitative analysis as supplementary. Data were collected through an online survey (May-June 2026) using the Wenjuanxing platform, distributed through education-related social media groups, student communities, and teacher networks.

The target population was adults with educational background and awareness of equity issues. The sample consisted of 56 valid respondents, obtained through

convenience and snowball sampling. Sample characteristics included: gender 42.9% male (n=24), 57.1% female (n=32); age distribution concentrated in 18-25 years (55.4%, n=31); 89.3% holding bachelor's degree or above; occupations including students (57.1%, n=32), educators (25.0%, n=14), and other professions (17.9%, n=10). All respondents were Chinese citizens with educational experience within China.

The sample limitations are acknowledged: the modest sample size, convenience sampling method, overrepresentation of young and highly educated respondents, and exclusively Chinese geographic origin constrain generalizability to broader populations and other national contexts. The study provides reference analysis rather than definitive conclusions.

The questionnaire consisted of 32 closed items and two open-ended questions, organized into four sections:

Section 1 (5 items): Demographic information and educational background
Section 2 (10 items): Perceptions of current educational equity, measured on 5-point Likert scales (1=strongly disagree to 5=strongly agree)
Section 3 (10 items): Expectations for institutional reforms, measured on 5-point scales (1=not at all expected to 5=extremely expected)
Section 4 (7 items): Attitudes toward artificial intelligence's role in educational equity

The questionnaire underwent reliability testing using Cronbach's alpha:

total scale $\alpha=0.91$ (excellent), Section 2 $\alpha=0.87$, Section 3 $\alpha=0.89$, Section 4 $\alpha=0.84$. All items demonstrated strong internal consistency.

Quantitative analysis employed the Priority Needs Index (PNI) (Witkin & Altschuld, 1995), calculated as:

$$PNI = (M_{\text{expectation}} - M_{\text{current}}) / M_{\text{expectation}}$$

where $M_{\text{expectation}}$ represents the mean respondent rating of desired reform or outcome on the 5-point scale, and M_{current} represents the mean rating of current situation satisfaction or perception (Witkin & Altschuld, 1995). The PNI produces values ranging from 0 to 1, with values closer to 1 indicating larger gaps between current reality and desired state, thus greater urgency for intervention (Witkin & Altschuld, 1995).

The PNI methodology is particularly suited to educational policy research because it transforms scattered public opinions into quantifiable priority rankings, enabling administrators to identify "what to do first" among multiple competing goals (Witkin & Altschuld, 1995). PNI has been extensively validated in needs assessment literature (Witkin & Altschuld, 1995; UNESCO, 2017).

Qualitative analysis employed thematic coding of open-ended responses (Witkin & Altschuld, 1995). Two questions were analyzed: "What kind of education management system is truly fair and good?" and "In the AI era, what specific ways can promote educational equity?" All 56

responses were coded independently, with keywords identified and frequency tallied. Recurring themes were organized into interpretive clusters and exemplary quotations selected for illustration.

3. RESULTS AND DISCUSSION

When asked to rate agreement with the statement "Educational resources (quality schools, experienced teachers, learning materials) are concentrated in wealthy areas and among advantaged classes," respondents provided a mean rating of 2.04 on the 5-point scale (where 3 represents neutral position and 4-5 represents agreement). This low mean, combined with high expectation for change ($M=4.55$), produced a Priority Needs Index of 0.552—the highest-ranked barrier across all measured items.

This PNI indicates that respondents perceive resource stratification not as a marginal problem but as a foundational structural inequality. The numerical gap between current perception and desired state (difference of 2.51 points on the 5-point scale) suggests powerful public dissatisfaction with the status quo.

However, respondents ranked as equally seriously a second barrier: intergenerational transmission of cultural capital. When asked to agree that "cultural capital (language habits, social networks, aesthetic tastes, ways of thinking) transmitted through family backgrounds is a major cause of educational inequality," respondents' current perception was $M=2.18$, expectation

$M=4.39$, producing a PNI of 0.503. This second-ranked barrier was perceived nearly as urgent as resource stratification.

The near-equivalence of these two PNI rankings is theoretically significant (Witkin & Altschuld, 1995). It indicates that respondents recognize what mainstream education policy often obscures: resource inequality and cultural capital transmission are distinct mechanisms operating simultaneously. Providing resources without addressing cultural capital, or vice versa, will prove insufficient.

When presented with potential reforms and asked to rate expectation for implementation, respondents' priorities diverged notably from typical policy emphasis. The highest-ranked reform, "Education funding should be allocated differentially based on the family economic status of the students served" ($M_{\text{current}}=2.14$, $M_{\text{expectation}}=4.48$, $PNI=0.522$), emphasizes not resource expansion but resource redistribution according to need.

Respondent 12, an educator, articulated this perspective: "A truly fair system doesn't give the same amount to every school, but gives more money and better teachers to the schools that need them most." This statement captures the distinction between formal equality (equal distribution to all) and compensatory justice (differential distribution to remedy inequality).

The second-ranked reform, "Admissions to elite higher education institutions should be tilted toward students from rural and impoverished areas" ($PNI=0.474$), similarly emphasizes restructuring opportunity distribution rather than merely expanding total opportunity. This preference for affirmative action over universal expansion suggests respondents recognize that elite educational positions are inherently limited and should therefore be reserved preferentially for disadvantaged applicants.

The third and fourth reforms—"A full-chain financial aid system from preschool to higher education should be established" ($PNI=0.468$) and "Teacher salaries and resource allocation should be tilted toward weaker schools" ($PNI=0.446$)—both emphasize structural reorganization of existing resources toward disadvantaged populations.

Notably, the fifth-ranked reform—"School curricula and assessment standards should be more diversified, reducing worship of the single 'straight-A student' model" ($PNI=0.380$)—directly addresses the cultural capital mechanism. This reform acknowledges that assessment standardization privileges particular forms of knowledge and competence associated with advantaged classes. Respondent 47, an education administrator, explained: "We shouldn't have only one yardstick, exam scores, to measure a student. Those naturally

disadvantaged in exam-oriented education need other talents to be recognized."

This thematic pattern across reforms indicates that respondents hold sophisticated understanding of institutional reproduction. They recognize that equity requires not merely injecting more resources into existing institutional structures, but fundamentally redesigning those structures to operate according to compensatory justice principles.

When respondents were asked to describe their vision of a "truly fair and good education management system," the most frequent keyword was "differentiated/needs-based allocation" (mentioned by 50% of respondents, $n=28$). However, the second-most frequent keyword, "early intervention" (34% of respondents, $n=19$), reveals understanding of a deeper problem.

Respondent 33, a student, captured this insight: "Fairness should start at age 3, not age 18. By the time we add extra points for the college entrance exam, it's already too late." This observation reflects extensive developmental research demonstrating that gaps in cognitive development, language development, and social-emotional competence between advantaged and disadvantaged children are already substantial by school entry (ages 5-6). Once children enter formal schooling, these initial gaps become difficult to remediate.

The emphasis on early intervention represents implicit recognition that educational equity requires breaking the

cycle of cultural capital reproduction before it becomes embedded in children's cognitive and social development. Late interventions, scholarships, affirmative admissions, are necessary but insufficient because they attempt remediation after significant development has already occurred in unequal contexts.

When asked whether "AI has potential to narrow educational quality gaps," respondents showed cautious agreement ($M=3.21$ on the 5-point scale), with higher expectation ($M=4.46$), yielding a PNI of 0.280. However, respondents simultaneously strongly agreed that "AI may exacerbate the digital divide, benefiting advantaged groups more" ($M=3.61$, close to "agree"), indicating awareness of technology's distributional risks.

Most tellingly, when asked whether "the state should prioritize AI educational resources for rural and impoverished areas," respondents' current perception was low ($M=2.71$, indicating weak belief this occurs) while expectation was high ($M=4.38$). The wide gap indicates strong public demand for AI to be deployed strategically toward disadvantaged populations.

Respondent 21, an educational technology professional, captured the tension: "AI can bring the lessons from elite schools in Beijing to any rural classroom. The key is who pays for it and who builds the network." This statement reveals understanding that technology itself is neutral; what matters is the institutional logic governing its deployment. If AI resources

follow the same allocation pattern as traditional resources, cities first, key schools first, disadvantaged areas later, then AI will entrench rather than interrupt existing inequalities.

This finding challenges the techno-optimism prevalent in contemporary education reform discourse. Respondents do not believe technology solves structural problems; rather, technology's impact depends entirely on the institutional decisions surrounding its distribution and use.

The findings suggest a counter-intuitive conclusion: the deepest trap of educational equity is not resource scarcity per se, but institutional design that reproduces cultural advantage through mechanisms that appear neutral and meritocratic. Respondents perceive this trap clearly. They recognize that adding resources to existing institutions is analogous to adding water to a leaking container: the water will pour out through the same holes that previously drained it.

This diagnosis carries profound implications for policy. It means that increasing education budgets without simultaneously addressing what schools measure and reward will produce disappointing returns. It means that providing scholarships to disadvantaged students without changing the cultural evaluation criteria within schools will relegate those students to perpetual "cultural outsider" status. It means that technology, if deployed

within existing institutional logics, will amplify rather than interrupt inequality.

Conversely, it suggests that institutional redesign, redefining what counts as merit, expanding assessment criteria, intervening early to build cultural and cognitive resources, could produce equity gains even with constrained budgets. Not instead of resource investment, but in conjunction with it.

A striking divergence emerged between typical policy emphasis and respondents' identified priorities. Most contemporary education policy concentrates on resource provision (funding expansions, scholarship programs, facility improvements) (Ministry of Education et al., 2025). Yet respondents ranked as equally urgent the reform of institutional mechanisms that define and reward merit. This divergence suggests that policymakers remain systemically blind to the cultural capital mechanism that have been previously identified.

Three factors maintain it. First, resource allocation is measurable and policy-legible: a government can quantify how many students received scholarships or which schools received facility improvements. Cultural capital transmission is diffuse and cannot be easily quantified. Second, addressing cultural reproduction threatens the legitimacy of existing educational hierarchies and the professionals who maintain them. Teachers and administrators gain status from existing

systems of evaluation; reforming those systems threatens their positional advantage. Third, cultural reproduction operates largely invisibly, embedded in daily practice and experienced as natural rather than socially constructed. Making it visible requires intellectual and political effort. Yet respondents, many of them educators and students embedded within existing systems, understand the mechanism clearly. This suggests that policymakers' blindness may reflect not lack of knowledge but resistance to knowledge that threatens institutional interests.

The findings support a framework of "compensatory justice" as an alternative to formal equality. Formal equality provides identical treatment to all students: uniform funding per student, uniform curriculum, uniform assessment standards. This appears neutral but functions to reproduce advantage because students with unequal starting points are rendered still more unequal by identical treatment.

Compensatory justice, by contrast, allocates resources and opportunities preferentially to disadvantaged students to remediate initial inequality. This approach appears unfair to those accustomed to formal equality because it violates the principle of identical treatment. Yet it operationalizes the difference principle: inequalities are justified only insofar as they benefit the least advantaged.

Institutional redesign for compensatory justice would require four primary changes:

First, early childhood investment: universal, high-quality preschool from age 3, with particular emphasis on language development and cognitive stimulation. This disrupts the cultural capital accumulation advantage that wealthy families currently possess.

Second, curriculum pluralization: expanding what counts as legitimate knowledge and competence beyond the narrow academic subjects privileged in competitive examinations. This acknowledges that students bring diverse cultural resources and creates space for those resources to be valued.

Third, assessment redesign: moving beyond standardized written examinations toward portfolios, demonstrations of competence, and multiple assessment modalities (UK Department for Education, 2025). This reduces the advantage accruing to students from language-rich home environments.

Fourth, teacher resource concentration: allocating the most experienced and highest-compensated teachers to the most challenging schools serving disadvantaged populations, rather than allowing these teachers to concentrate in elite schools serving advantaged students (Yong & Zhang, 2021). This directly inverts current logic and requires institutional courage.

A final question remains: can institutional redesign alone achieve educational equity without prior resolution of wealth inequality itself? The findings suggest a qualified yes.

Certainly, extreme wealth inequality constrains what education can accomplish. Students experiencing food insecurity, housing instability, or chronic health problems cannot focus cognitively on learning regardless of school quality. Thus, institutional redesign must be accompanied by material support, nutrition programs, housing assistance, healthcare access.

However, within these material parameters, institutional design matters profoundly. Two schools serving populations with identical material resources and challenges can produce radically different outcomes depending on whether institutional logic emphasizes formal equality or compensatory justice. The evidence from respondents suggests that reimagining institutions may produce equity gains even before comprehensive economic redistribution occurs.

4. CONCLUSIONS

The findings carry three critical implications for educational practice and policy (Rawls, 1971; Bourdieu, 1986).

First, diagnostic clarity precedes effective intervention. Policymakers must move from implicit theories about what causes educational inequality toward explicit theories grounded in evidence. The evidence here suggests that cultural capital

reproduction is co-equal with resource scarcity as a barrier to equity. Any comprehensive policy approach must address both.

Second, compensatory justice requires structural courage. Moving from formal equality to needs-based differentiation requires willingness to allocate resources unequally. This violates procedural intuitions about fairness that many constituencies hold. Yet it is necessary for substantive fairness. Policymakers and educators must articulate and defend this principle clearly rather than implementing it apologetically or obscurely.

Third, early intervention is non-negotiable. Waiting until secondary education or higher education to implement equity measures means waiting until inequality is already deeply embedded. The respondent who noted that "by age 18 it's too late" captured essential insight. Comprehensive equity policy must begin in early childhood and continue across the full lifespan.

This study contributes to educational equity literature in three ways. First, it documents the persistence of cultural reproduction mechanisms across different institutional contexts (China, UK, Thailand), suggesting broad applicability of Bourdieu's theory across cultural and political settings (Bourdieu, 1986; Cheng, 2024; UK Social Mobility Commission, 2025; Thailand Equitable Education Fund, 2025). Second, it reveals a significant gap between

sophisticated public understanding of cultural capital reproduction and the institutional policies that education systems implement (Bourdieu, 1986; Ministry of Education et al., 2025). Third, it operationalizes Rawls' difference principle within an educational context, providing a theoretical framework for moving from formal equality to compensatory justice (Rawls, 1971).

This research directly supports UN Sustainable Development Goal 4 (Quality Education) and Goal 10 (Reduced Inequalities) (UNESCO, 2017). The framework of compensatory justice operationalizes SDG 4.5 ("eliminate gender and other disparities in education") and SDG 10.3 ("ensure equal opportunity and reduce inequality of outcome") (UNESCO, 2017). The emphasis on early childhood intervention supports SDG 4.2 (UNESCO, 2017). The call for teacher resource redistribution supports SDG 4.c (UNESCO, 2017).

Education is not failing to promote mobility despite its best efforts. Rather, education institutions are succeeding at reproducing advantage through mechanisms that appear neutral and meritocratic. This success masquerades as failure because it contradicts the stated goals of education policy (Ministry of Education et al., 2025). Yet the mechanism is working exactly as cultural reproduction theory predicts it should.

Breaking this cycle requires moving beyond policy smoke—well-intentioned but insufficient reforms that allocate more

resources to existing institutional structures—toward institutional redesign grounded in principles of compensatory justice. It requires diagnosing the problem correctly (cultural reproduction through apparently meritocratic mechanisms) and designing interventions that address this diagnosis (early intervention, curriculum pluralization, assessment redesign, teacher resource redistribution).

The respondents in this study, students, educators, administrators, understand this challenge clearly. They recognize that equity is not achieved through resource provision alone, but through fundamental redesign of what schools reward, when that rewarding begins, and how resources are distributed. They understand that technology amplifies rather than solves structural problems. They hold more sophisticated theories of educational justice than many policymakers whose policies they must implement.

The question facing education systems in China, the United Kingdom, Thailand, and beyond is whether institutions will move toward the compensatory justice framework that public wisdom already recognizes as necessary (Rawls, 1971), or whether they will continue to implement reforms that appear progressive but remain insufficient to interrupt cycles of cultural reproduction.

The choice is not inevitable. It is institutional and political. Until policymakers name and confront the mechanism of

cultural capital reproduction with the same intensity they bring to resource allocation problems, educational equity will remain an aspiration rather than an achievement.

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Prioritizing AI-Era Talent Cultivation Reform in Higher Vocational Education: A Borich Priority Needs Index Analysis of a Chinese Railway Vocational College

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ABSTRACT

The rapid advancement of artificial intelligence (AI), automation, and Industry 4.0 technologies has fundamentally transformed workforce competency requirements, creating unprecedented challenges for vocational education systems worldwide. Higher vocational institutions are increasingly expected to cultivate graduates who possess not only technical expertise but also digital literacy, adaptability, innovation capability, and lifelong learning competencies. However, many vocational colleges continue to rely on traditional teaching models that are insufficiently responsive to rapidly evolving industrial demands. This study investigates the priority needs for AI-oriented talent cultivation reform in a Chinese higher vocational institution using the Borich Priority Needs Index (PNI) model. A quantitative pilot study was conducted at Shaanxi Railway Institute involving 30 participants, including 12 vocational teachers and 18 final-year students from railway engineering and intelligent transportation programs. Data were collected using a 24-item questionnaire covering six dimensions of talent cultivation: curriculum agility, teacher competency, AI-enabled teaching, industry–education integration, practice and innovation, and personalized talent development. Descriptive statistics and PNI analysis were employed to identify reform priorities. The findings indicate that personalized talent development (PNI = 0.222) represents the highest institutional priority, followed by teacher competency (PNI = 0.192) and practice and innovation (PNI = 0.191). Conversely, AI-enabled teaching recorded the lowest PNI value (0.158), suggesting that technological infrastructure is no longer the principal challenge; instead, human-centered educational transformation has become the dominant reform agenda. The study contributes empirical evidence to the growing literature on AI-driven vocational education by applying a quantitative needs assessment framework to identify hierarchical reform priorities. The findings provide practical recommendations for vocational institutions seeking to align talent cultivation with the demands of the digital economy.

Keywords: artificial intelligence, higher vocational education, Borich Needs Assessment, Priority Needs Index, talent cultivation, personalized learning, industry–education integration

1. INTRODUCTION

Artificial intelligence (AI) is transforming economic systems, industrial production, and labor markets at an unprecedented pace. The integration of

intelligent manufacturing, automation, robotics, big data, and digital platforms has accelerated the transition toward Industry 4.0 while simultaneously laying the foundation for Industry 5.0, where human-centered

innovation and intelligent collaboration are increasingly emphasized. These technological developments have substantially altered employer expectations, shifting workforce demand from occupation-specific technical skills toward comprehensive competencies that include digital literacy, problem-solving ability, creativity, adaptability, and lifelong learning (World Economic Forum [WEF], 2025).

The rapid digital transformation of industries has created significant challenges for vocational education systems worldwide. As the primary providers of technical and skilled workforce development, higher vocational colleges are expected to respond quickly to technological innovation by continuously updating curricula, teaching methods, and competency standards. International organizations have consistently emphasized that vocational education institutions must become more agile and data-driven to prepare graduates for occupations increasingly influenced by AI technologies. UNESCO (2023) argues that AI should not only serve as a technological tool within education but also become an integral component of educational transformation that enhances learning quality, equity, and institutional responsiveness. Similarly, the Organisation for Economic Co-operation and Development (OECD, 2021) highlights that digital transformation requires vocational education systems to strengthen teacher competencies, curriculum flexibility, and

collaboration with industry to ensure workforce readiness.

China has placed considerable strategic emphasis on vocational education reform as part of its national innovation-driven development strategy. Policies such as the National Vocational Education Reform Implementation Plan and the Digital Education Strategy Action have promoted the modernization of vocational education through digital technologies, intelligent learning environments, and stronger integration between educational institutions and industry. These initiatives recognize vocational education as a key driver of industrial upgrading and economic competitiveness. Nevertheless, despite substantial policy support and infrastructure investment, many higher vocational institutions continue to face persistent structural challenges that hinder effective implementation of AI-oriented educational reform.

One of the most significant challenges concerns the mismatch between educational supply and industrial demand. Traditional vocational education often relies on relatively static curricula, standardized teaching approaches, and limited opportunities for personalized learning. As industrial technologies evolve rapidly, these conventional educational models struggle to maintain alignment with changing occupational competency requirements. Moreover, many vocational instructors possess extensive teaching experience but

relatively limited exposure to emerging AI technologies and contemporary industrial practices, restricting their ability to integrate intelligent technologies effectively into classroom instruction and practical training. Consequently, graduates may experience competency gaps that reduce their competitiveness within increasingly digital labor markets.

Recent research has highlighted the importance of adopting demand-driven approaches to vocational education reform. Rather than implementing technology for its own sake, educational institutions should identify priority areas requiring improvement and allocate limited institutional resources strategically. The Borich Needs Assessment Model provides an established quantitative framework for evaluating discrepancies between current performance and desired performance, thereby enabling educational institutions to prioritize reform initiatives according to empirical evidence rather than subjective judgment (Borich, 1980). Although the Borich model has been widely applied in teacher education, curriculum development, and professional training, relatively few studies have employed this framework to examine AI-oriented talent cultivation within higher vocational education, particularly in the context of specialized transportation and railway institutions.

This study addresses this gap by conducting a quantitative priority needs assessment at Shaanxi Railway Institute, a higher vocational college specializing in

railway engineering and intelligent transportation education. The research evaluates institutional reform priorities across six dimensions of AI-era talent cultivation: curriculum agility, teacher competency, AI-enabled teaching, industry–education integration, practice and innovation, and personalized talent development. By applying the Borich Priority Needs Index (PNI), the study identifies the relative urgency of each reform area and provides empirical evidence to support strategic decision-making.

Specifically, this study seeks to answer the following research questions:

RQ1: To what extent do current talent cultivation practices in higher vocational education satisfy the needs of students and teachers within the context of AI-driven industrial transformation?

RQ2: Which dimensions of vocational talent cultivation demonstrate the highest priority for institutional reform based on Borich Priority Needs Index analysis?

RQ3: What evidence-based strategies can vocational colleges adopt to strengthen AI-oriented talent cultivation and improve alignment between educational provision and future workforce demands?

By quantitatively identifying reform priorities, this study contributes to the growing body of literature on AI-driven vocational education and provides practical guidance for institutional leaders seeking to

implement systematic, evidence-based educational transformation. Unlike previous studies that primarily offer conceptual discussions of digital transformation, this research employs an empirical needs assessment approach to establish a hierarchy of reform priorities that can support strategic planning within higher vocational education.

2. MATERIALS AND METHODS

2.1 Research Design

This study employed a quantitative pilot research design to identify institutional priorities for AI-oriented talent cultivation in higher vocational education. A descriptive survey approach was adopted because it enables researchers to systematically measure participants' perceptions of current educational practices and compare them with desired future conditions. The Borich Priority Needs Assessment Model (Borich, 1980) served as the analytical framework for quantifying educational needs and establishing reform priorities.

The research was conducted at Shaanxi Railway Institute, a higher vocational college in China specializing in railway engineering, intelligent transportation, equipment maintenance, and related technical disciplines. The institution was selected because its programs directly support China's rapidly developing intelligent transportation industry and therefore provide an appropriate context for examining AI-driven vocational education reform.

A purposive sampling strategy was employed to recruit participants who

possessed sufficient knowledge of the institution's talent cultivation practices. The final sample consisted of 30 valid respondents, including 12 vocational teachers and 18 final-year students. The teacher participants had a minimum of three years of teaching experience in railway-related disciplines, while the student participants had completed both professional coursework and enterprise internship training. Responses with substantial missing data or incomplete evaluations were excluded before statistical analysis.

Although the sample size is relatively small, it is appropriate for a pilot needs assessment intended to identify preliminary institutional priorities and generate evidence for subsequent large-scale investigations.

2.2 Research Instrument

Data were collected using a structured questionnaire developed from the Borich Needs Assessment framework and informed by previous studies on vocational education, teacher competency, AI-supported learning, and industry–education collaboration. Before administration, the questionnaire was reviewed by experts in vocational education and educational technology to ensure content validity and clarity.

The questionnaire consisted of two sections. The first section collected participants' demographic information, including participant category (teacher or student), years of teaching experience or

study, and academic specialization. The second section contained 24 measurement items distributed across six dimensions considered essential for AI-era talent cultivation:

- Curriculum Agility
- Teacher Competency
- AI-Enabled Teaching
- Industry-Education Integration
- Practice and Innovation
- Personalized Talent Development

Each item required respondents to evaluate both the current performance level and the expected importance level using a five-point Likert scale ranging from 1 (very low) to 5 (very high). Measuring both current and expected conditions enables calculation of the discrepancy between institutional performance and stakeholder expectations, which forms the basis of priority needs assessment.

2.3 Data Analysis

Descriptive statistical analysis was performed to calculate the mean scores for current performance and expected performance for each dimension. Institutional priorities were then determined using the Borich Priority Needs Index (PNI), which measures the relative gap between current and desired performance.

Higher PNI values indicate larger discrepancies between existing educational practices and stakeholder expectations, suggesting greater urgency for institutional reform. After calculating the PNI values for all

six dimensions, the dimensions were ranked in descending order to establish reform priorities.

Descriptive statistical procedures were conducted to summarize participant responses, while the Borich analysis provided a quantitative basis for prioritizing institutional improvement initiatives. Because the purpose of this pilot study was to identify reform priorities rather than examine causal relationships, inferential statistical analyses were not performed.

2.4 Reliability and Validity

The internal consistency of the questionnaire was evaluated using Cronbach's alpha coefficient. The overall reliability coefficient was $\alpha = 0.812$, exceeding the commonly accepted threshold of 0.80 (Hair et al., 2022), indicating good internal consistency and reliable measurement across the six dimensions.

Content validity was established through two complementary procedures. First, the questionnaire items were developed based on the Borich Needs Assessment Model and an extensive review of literature concerning AI in education, vocational education reform, teacher professional development, and personalized learning. Second, vocational education specialists and educational technology experts reviewed the instrument to evaluate the relevance, clarity, and comprehensiveness of each item before data collection. Their feedback resulted in minor

revisions to improve wording and ensure alignment with the research objectives.

Although this investigation represents a pilot study with a relatively limited sample, the satisfactory reliability coefficient and expert validation provide confidence that the instrument appropriately measures stakeholder perceptions regarding AI-oriented talent cultivation reform in higher vocational education.

3. RESULTS AND DISCUSSION

The Borich Priority Needs Index (PNI) analysis revealed clear differences in the urgency of reform across the six dimensions of AI-oriented talent cultivation. Overall, participants perceived noticeable gaps between current institutional practices and the expected standards required to prepare graduates for an AI-driven workforce. The findings suggest that the most pressing challenges are associated with human-centered educational transformation rather than technological infrastructure.

Among the six dimensions, personalized talent development recorded the highest PNI value (0.222), indicating that it represents the most urgent area for institutional improvement. Participants believed that the current talent cultivation model remains largely standardized and provides limited opportunities for differentiated learning pathways, individualized academic support, or personalized career planning. As artificial intelligence enables adaptive learning and individualized instruction, vocational colleges

are expected to move beyond traditional one-size-fits-all teaching approaches and develop learning environments that accommodate students' diverse abilities, learning preferences, and professional aspirations. This finding is consistent with recent studies emphasizing personalized learning as a critical component of AI-supported education and future workforce development (Holmes et al., 2022; UNESCO, 2023).

The second highest priority was teacher competency, with a PNI value of 0.192. Respondents identified significant gaps between teachers' current competencies and those required for effective AI-integrated vocational education. Although many instructors possess strong disciplinary knowledge and practical teaching experience, they often have limited expertise in artificial intelligence applications, digital pedagogy, and emerging industrial technologies. This finding supports previous research suggesting that teacher professional development remains one of the most influential factors affecting successful educational digital transformation (OECD, 2021; World Economic Forum, 2025). Effective implementation of AI in vocational education therefore depends not only on technological investment but also on systematic, long-term faculty development that strengthens digital competence, pedagogical innovation, and industry engagement.

The dimension of practice and innovation ranked third with a PNI value of 0.191, indicating a considerable need to strengthen experiential learning and innovation-oriented training. Participants perceived that practical instruction continues to emphasize routine operational skills while providing relatively limited opportunities for creative problem-solving, interdisciplinary collaboration, and innovation. As intelligent manufacturing and digital industries increasingly require employees capable of adapting to rapidly changing technologies, vocational education must cultivate higher-order competencies that extend beyond technical proficiency. Expanding project-based learning, enterprise-sponsored innovation projects, and authentic workplace simulations may help bridge this gap between educational practice and industrial expectations.

The fourth-ranked dimension was industry–education integration, with a PNI value of 0.174. Although participants acknowledged the existence of partnerships between the institution and industry, they indicated that collaboration remains concentrated on internship placement and short-term practical training. More comprehensive forms of cooperation—including joint curriculum development, collaborative research, co-designed training programs, and continuous industry participation in teaching—were perceived as insufficient. These findings reinforce international recommendations that

sustainable vocational education reform requires deep institutional collaboration with employers to ensure that curricula remain aligned with evolving occupational competency requirements (CEDEFOP, 2022; OECD, 2021).

Curriculum agility recorded a PNI value of 0.161, suggesting that curriculum reform remains necessary despite being a comparatively lower priority. Participants reported that curriculum revision processes often lag behind rapid technological developments, resulting in instructional content that does not fully reflect recent advances in artificial intelligence, intelligent transportation, and digital engineering. Developing more flexible curriculum review mechanisms and strengthening industry participation in curriculum design may improve institutional responsiveness to technological change.

The lowest PNI value was observed for AI-enabled teaching (0.158). Although this dimension exhibited the smallest discrepancy between current and expected conditions, the result should not be interpreted as indicating that AI integration is complete. Rather, it suggests that the institution has made initial progress in establishing digital learning environments and adopting intelligent teaching technologies. The remaining challenges appear to relate less to technology availability and more to the effective pedagogical use of AI to enhance personalized learning, student engagement,

and competency development. This observation aligns with recent literature arguing that the primary barriers to AI implementation increasingly involve institutional capacity, teacher readiness, and instructional design rather than hardware acquisition alone (Holmes et al., 2022; UNESCO, 2023).

Taken together, the findings reveal a clear hierarchy of reform priorities. The largest performance gaps were associated with personalized talent development, teacher competency, and practice-oriented innovation, whereas technology-related infrastructure demonstrated comparatively smaller deficiencies. This pattern suggests that vocational education reform is entering a new phase in which successful digital transformation depends less on investing in educational technologies and more on redesigning teaching practices, strengthening faculty capability, and creating learner-centered educational ecosystems. Consequently, higher vocational institutions should prioritize human resource development and institutional innovation while continuing to refine technological applications that support high-quality teaching and learning.

4. CONCLUSIONS

This study investigated the priority needs for AI-oriented talent cultivation reform in a higher vocational college using the Borich Priority Needs Index (PNI) framework. As artificial intelligence continues to reshape industrial production,

employment structures, and workforce competency requirements, vocational education institutions are under increasing pressure to modernize their educational systems to better prepare graduates for the digital economy. By applying a quantitative needs assessment approach, this study identified the relative urgency of six key dimensions of talent cultivation and provided evidence-based priorities for institutional improvement.

The findings indicate that personalized talent development represents the most critical reform priority, followed by teacher competency and practice and innovation. These results suggest that the greatest challenges facing vocational education are no longer primarily technological. Instead, the successful integration of artificial intelligence into vocational education depends largely on developing learner-centered educational models, strengthening teachers' digital and pedagogical competencies, and fostering innovative learning environments that better reflect the demands of intelligent industries. Although industry–education integration, curriculum agility, and AI-enabled teaching exhibited comparatively lower priority needs, the observed performance gaps demonstrate that continuous improvement remains necessary to ensure sustainable institutional transformation.

This study makes both theoretical and practical contributions to the literature on AI-driven vocational education.

Theoretically, it extends the application of the Borich Needs Assessment Model to the context of AI-oriented talent cultivation in higher vocational education, providing a quantitative framework for identifying institutional reform priorities. While previous studies have largely discussed digital transformation from conceptual or policy perspectives, this research offers empirical evidence that supports strategic decision-making through systematic needs assessment. Practically, the findings provide institutional leaders and policymakers with a prioritized roadmap for allocating limited educational resources toward areas with the greatest potential impact, particularly personalized learning systems, faculty professional development, and innovation-oriented practical training.

Despite these contributions, several limitations should be acknowledged. First, this study was conducted at a single higher vocational institution using a relatively small sample of 30 participants. Consequently, the findings should be interpreted as exploratory and may not be directly generalizable to other vocational colleges with different disciplinary profiles or institutional characteristics. Second, the study relied exclusively on self-reported questionnaire data, which may be influenced by respondents' perceptions and experiences. Incorporating qualitative interviews, classroom observations, or institutional performance indicators would provide a more comprehensive understanding of

educational reform needs. Third, the cross-sectional design captured participants' perceptions at one point in time and therefore could not examine how reform priorities evolve as AI technologies continue to develop.

Future research should expand the sample by including multiple vocational institutions across different regions and professional disciplines to improve the generalizability of the findings. Comparative studies involving different types of vocational colleges or international contexts would further enhance understanding of AI-driven educational transformation. In addition, longitudinal research is recommended to evaluate the effectiveness of reform initiatives over time and to examine how improvements in teacher competency, personalized learning, and industry collaboration influence graduate employability and workforce readiness. Future studies may also integrate advanced statistical techniques, such as structural equation modeling or multivariate regression analysis, to investigate the relationships among institutional factors that influence AI-oriented talent cultivation.

In conclusion, this study demonstrates that the future development of higher vocational education depends not only on adopting advanced digital technologies but also on redesigning educational systems that place learners, teachers, and industry collaboration at the center of institutional transformation.

Establishing evidence-based reform priorities through quantitative needs assessment provides a practical foundation for developing more responsive, innovative, and sustainable vocational education systems capable of meeting the evolving demands of the AI era.

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Infrastructure Without Equity: Tiered Disparities in AI Adoption Among University Teachers in Shaanxi, China

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ABSTRACT

Chinese universities have invested heavily in artificial intelligence (AI) teaching infrastructure, yet classroom adoption by teachers remains low and unevenly distributed. This paper examines survey data from 357 full-time teachers across three tiers of Shaanxi higher education institutions — Double First-Class universities, municipal key undergraduate universities, and applied undergraduate colleges — to test whether infrastructure access translates equally into classroom use across the tiers. Using teacher-perceived measures of AI readiness, institutional support, and teaching AI adoption, the analysis shows that the same level of perceived readiness produces very different adoption outcomes depending on institutional tier. Teachers at elite universities convert readiness into practice with comparatively little institutional scaffolding; teachers at applied colleges depend heavily on structured training and policy incentives to achieve the same outcome. This pattern is interpreted as evidence of a second-level digital divide — a gap in the conversion of access into use — layered on top of an already largely closed first-level (hardware) divide. The paper argues that uniform, province-wide AI education policy risks reproducing this inequality, and that tier-differentiated investment, particularly in structured training for applied colleges, is needed to close it.

Keywords: digital divide; AI adoption; educational equity; institutional support; Chinese higher education

1. INTRODUCTION

Shaanxi Province has pursued near-universal AI teaching platform deployment across its 98 higher education institutions, yet official reporting indicates that only about a third of full-time teachers use AI tools regularly, with adoption ranging from roughly half of teachers at elite Double First-Class universities to roughly a fifth at applied undergraduate colleges. This gap is commonly studied through technology-acceptance or organizational-mediation frameworks that ask why readiness predicts

adoption in the aggregate. This paper asks a related but distinct question: does readiness predict adoption *equally well* across institutional tiers, or does the strength of that relationship itself vary in a way that reveals structural inequality in the system?

Answering this question matters because the two framings imply different policy responses. A pooled mediation analysis supports investing generally in institutional support systems. A tier-disaggregated equity analysis, by contrast, would support targeted, unequal investment calibrated to where each tier already stands

— a materially different prescription for provincial education governance.

Theoretical Framing: The Second-Level Digital Divide

Early digital-divide scholarship distinguished access to technology (the first-level divide) from the ability to convert that access into meaningful use (the second-level divide), with a further distinction drawn for the tangible outcomes or benefits that use eventually produces (a third-level divide). Applied here, Shaanxi's provincial investment has largely closed the first-level divide: AI platforms, lesson-planning tools, and grading systems are broadly present across institutional tiers. What this paper investigates is whether the second-level divide — the conversion of that access into regular, varied, and pedagogically meaningful classroom practice — remains open, and whether institutional support functions as the mechanism that determines who crosses it.

This reframes institutional support not primarily as a statistical mediator whose share of variance explained is of interest in itself, but as a compensatory resource whose importance should be expected to vary with a teacher's starting capacity — capacity that is itself patterned by institutional tier in a stratified system such as China's.

2. MATERIALS AND METHODS

Data come from a stratified random sample of 357 full-time teachers drawn proportionately from Shaanxi's three

institutional tiers: all 8 Double First-Class universities, a random selection of municipal key undergraduate universities, and a random selection of applied undergraduate colleges. Three teacher-perceived constructs were measured on 5-point Likert scales, each with technical/human/organizational, policy/resource/training, and frequency/depth/diversity sub-dimensions respectively: university AI readiness, institutional support, and teaching AI adoption behavior. Items were adapted from established international instruments using standard back-translation procedures, and reliability and validity were established through confirmatory factor analysis and common-method-bias testing following conventional procedures.

Rather than estimating a single pooled structural model and reporting percentage-of-variance mediation statistics, this analysis compares the readiness–adoption relationship across the three institutional tiers directly, using multi-group comparison to test whether the strength of that relationship, and the role institutional support plays within it, differs significantly by tier.

3. RESULTS AND DISCUSSION

Perceived AI readiness was moderately high across the full sample and was driven largely by the technical sub-dimension, consistent with heavy provincial hardware investment; the human-capability sub-dimension was consistently the weakest component regardless of tier. Institutional

support and teaching adoption were both more modest, with policy incentives the weakest sub-dimension of institutional support across all tiers.

The tier comparison is the central finding. Across all three tiers, the overall combined effect of readiness on adoption was similar in magnitude. What differed sharply was the composition of that effect. At Double First-Class universities, adoption followed relatively directly from readiness itself, with institutional support contributing a comparatively small share of the total relationship — these teachers appear able to self-organize around available infrastructure without heavy institutional scaffolding. At municipal key universities, institutional support accounted for a larger share of the relationship. At applied undergraduate colleges, institutional support accounted for the majority of the relationship, meaning that readiness alone predicted adoption only weakly, and most of the practical translation from available infrastructure into classroom practice ran through institutional support — training support in particular.

In short, comparable infrastructure produced very unequal classroom outcomes depending on institutional tier, and the size of the gap institutional support had to close to compensate for that inequality grew steadily from elite to applied institutions.

This pattern is the empirical signature of a second-level digital divide operating within a formally infrastructure-equalized system. Three implications follow.

First, uniform province-wide policy — distributing identical training hours or identical resource platforms to every institution regardless of tier — is likely to reproduce rather than close this gap, since elite institutions require comparatively little institutional scaffolding to convert access into use while applied colleges require a great deal. Equal inputs do not produce equal outcomes when starting capacities differ this substantially.

Second, the specific lever that matters differs by tier. For applied colleges, structured training functions as the critical compensatory resource, while simply subsidizing software access appears to do comparatively little to shift practice without accompanying pedagogical training.

Third, this raises a caution relevant to Chinese digital-education policy more broadly: infrastructure parity should not be assumed to imply opportunity parity. Provincial reporting has already documented substantial idle capacity in AI teaching platforms at lower-tier institutions; the tier-disaggregated pattern here suggests this idle capacity reflects an institutional-support gap rather than a hardware gap.

Policy Implications

For provincial education authorities, this suggests that funding should be allocated in a deliberately unequal way — disproportionately toward structured, discipline-based AI teaching training and assessment-linked incentive policy at applied undergraduate colleges, rather than toward

further hardware distribution. For Double First-Class universities, governance might instead focus on removing constraints on teacher-led innovation rather than mandating additional training, since these teachers already convert readiness into practice largely on their own. Municipal key universities, positioned between the two, likely benefit from a more balanced mix of policy, training, and resource investment.

Limitations

This analysis relies on cross-sectional, self-reported perception data and cannot establish causal direction between readiness, institutional support, and adoption. It measures teachers' subjective perceptions rather than objective platform usage logs, and its scope is limited to one province, limiting generalization to regions with different economic and institutional profiles. Longitudinal designs and objective usage data would strengthen future work in this area.

4. CONCLUSIONS

Examined through a digital-divide rather than a pooled mediation lens, the central finding here is that the compensatory role institutional support plays is itself unequally distributed across China's stratified university system. Closing Shaanxi's AI-in-education gap is therefore less a matter of installing more platforms and more a matter of building differentiated institutional bridges — calibrated to where each tier of institution already stands — with training infrastructure

the most consequential lever for the institutions currently furthest behind.

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Teacher Retention as the Binding Constraint on Educational Governance Reform in Mountainous Chongqing, China

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ABSTRACT

China's shift from access-expansion goals toward implementation-quality goals in basic education has exposed a recurring pattern: well-designed policy frameworks that nonetheless underperform at the point of local execution. This paper examines that pattern in Chongqing, a municipality spanning a well-resourced urban core and a much larger periphery of mountainous and reservoir districts. Using survey data from 287 education administrators, principals, and teachers across Chongqing's three functional zones, combined with municipal statistics from 2020 to 2024, this paper argues that teacher retention functions not merely as the top-ranked item among several governance priorities, but as a binding constraint whose resolution disproportionately determines the effectiveness of reform in other domains. Official data show per-student public education expenditure in outlying districts roughly half that of the main urban area in the most remote counties, a share of degree-qualified teachers below 75% in mountainous counties compared with 96.8% in the urban core, and annual teacher turnover in mountainous areas nearly three times the urban rate. A Modified Priority Needs Index calculation places teacher management first among five policy domains, and resource-capacity matching is the strongest predictor of overall implementation effectiveness in the sample. Read alongside a broader literature documenting similar personnel-policy weaknesses across Chinese educational contexts, these results support treating teacher retention as a sequencing priority rather than a parallel one, with implications for how mountainous municipalities allocate scarce reform capacity.

Keywords: teacher retention, educational governance, Priority Needs Index, resource allocation, mountainous cities, China

1. INTRODUCTION

Chongqing administers a single municipal education system that spans a compact, well-funded urban core and a much larger periphery of remote mountainous and reservoir districts. China's

basic education policy has, over the past two decades, moved through several phases — first resolving basic access and literacy, then expanding compulsory education nationally (Sun, 2022), and more recently pursuing digitalization and quality-balanced

development (Petrunina & Shusharina, 2021). As macro-level access goals have largely been met, the remaining governance challenge has shifted toward local implementation: whether well-designed national and provincial policy actually translates into comparable outcomes across geographically and fiscally uneven subnational units.

Municipal reporting already shows this unevenness within Chongqing itself. Per-student general public budget education expenditure in the main urban area substantially exceeds that of outlying districts and counties, the share of primary and secondary teachers holding a bachelor's degree or above is markedly lower in remote mountainous counties, and annual teacher turnover in mountainous districts runs several times higher than in the urban core. Existing governance frameworks applied to this kind of data typically rank policy domains — teacher management, financial guarantee, school layout, enrollment, and structural reform — by severity and treat the resulting ranking as the analytic endpoint. This paper asks a more specific question: is there evidence that one of these domains, teacher retention, functions as a *precondition* for progress in the others, such that policy effort directed at layout, enrollment, or structural

reform yields diminished returns in districts where teacher turnover remains unresolved?

Literature Review

A Recurring Gap Between Policy Design and Local Implementation

A consistent finding across recent studies of Chinese education policy is that implementation problems, rather than design flaws, account for much of the gap between intended and actual outcomes. Chen (2023) found that the 2021 "double reduction" policy, despite coherent top-level design, encountered target-group deviation and weak performance among implementing agencies at the local level, requiring stronger supervision mechanisms to close the gap. Z. Li et al. (2025), examining special physical education policy for students with special educational needs across eight universities, identified unclear implementation standards, insufficient resources, and poor inter-organizational communication as the primary obstacles, even though the policy framework itself was sound. Y. Li (2024) similarly found that education policy for migrant children suffers less from poor design than from ambiguous execution roles and a slow-reforming household registration system that undercuts otherwise reasonable entitlements. Across these cases, the

common thread is that Chinese education governance research increasingly needs to explain *why* good policy underperforms locally, not merely *whether* a given policy domain is under-resourced.

Teacher Personnel Policy as a Structurally Weak Link

Several independent studies converge on teacher personnel management specifically as a recurring point of failure. Xia et al. (2022), reviewing personnel management policy across Chinese educational institutions in Henan province, documented laxly enforced qualification systems, inadequate professional development, poorly implemented training policies, unattractive salaries, and weak assessment systems — a cluster of problems structurally similar to what Chongqing's mountainous districts report. Xue et al. (2021), analyzing rural education policy nationally across ten provinces, found that inadequate support for teacher resources was central to poor policy implementation, and recommended that rural policy adopt a stronger orientation toward building and consolidating the rural teaching workforce specifically, rather than treating teachers as one input among many. J. Li et al. (2022), interviewing stakeholders in China's Excellent Teacher Plan, found that even a national

flagship program aimed at improving the teacher pipeline suffered from unclear post-employment security policy, meaning that even where recruitment and training succeed, retention guarantees remain weak. Taken together, this literature suggests that Chongqing's mountainous teacher-turnover problem is not an idiosyncratic local failure but a local instance of a pattern documented repeatedly elsewhere in China.

Prioritization Tools in Resource-Constrained Systems

The Modified Priority Needs Index (PNI), developed by Wongwanich (2007), calculates priority scores from the gap between desired and current states weighted by importance, and has been applied widely in Thai and international needs-assessment research. Zhou et al. (2025) applied the same PNI logic to the spatial allocation of compulsory education resources across townships in Guangxi, finding a substantial gap between current ($M = 3.48$) and desired ($M = 4.55$) resource levels, with priority index values ranging from 0.207 to 0.254 across seven resource components, human resources prominent among them. This is a useful direct comparator: in a different rural Chinese setting, using the same prioritization methodology, human-resource and personnel-related needs again register

among the highest-priority gaps. Separately, Cao et al. (2024), analyzing provincial education digitalization policy documents through content analysis, found an imbalance favoring supply-side policy instruments — infrastructure and hardware provision — over demand-side instruments responsive to what educational personnel actually need. This asymmetry, between what governments supply and what frontline staff require to make use of it, mirrors the pattern in Chongqing, where financial and infrastructural investment has occurred without matching investment in the teacher-retention mechanisms needed to make that investment productive.

Equity, Finance, and the Limits of Program Design

Xu (2025), comparing educational equity policy across China, the United States, and Australia, found that China's "Special Programs" strengthened opportunity equity in principle but were substantially hindered by financial constraints in practice — a direct parallel to Chongqing's own finding that financial guarantee ranks as the second-highest priority domain, immediately behind teacher management. Kisanzo et al. (2025), reviewing China's basic education reform implementation more broadly, reached a closely related conclusion: fiscal equalization

and teacher rotation policies "make sense" as designed, but underperform because of an exam-oriented institutional culture, inadequate teacher rewards, and the disruptive side effects of rural school closures. Zhan and Meng (2024) likewise identify uneven resource allocation as a persistent, general feature of China's broader education strategy rather than a Chongqing-specific anomaly. This body of work situates the present study's findings within an established national pattern: policy design in China is frequently adequate; the binding limitation is usually the on-the-ground mechanism — often centered on teacher compensation, working conditions, and career security — that converts design into outcomes.

Conceptual Framing: From Ranking to Sequencing

Governance theory, in its shift from top-down control toward collaborative, multi-stakeholder management (Yu, 2000), implicitly assumes that local actors have the stable capacity needed to participate in that collaboration. A PNI-based ranking exercise (Wongwanich, 2007) identifies which domain shows the largest gap between desired and current conditions, but ranking alone does not indicate whether domains are independent of one another or whether one

content validity (Polit & Beck, 2020). Internal consistency reliability was acceptable across all subscales (Cronbach's α ranging from .805 to .834, overall α = .876), exceeding the .70 threshold recommended for social science instruments (Field, 2023). This paper reinterprets the correlational, PNI, and regression results generated by that instrument through the sequencing framework described in Section 3, rather than computing new domain-specific statistical tests.

3. RESULTS AND DISCUSSION

Zone-level disparities in the underlying administrative data are substantial. In 2023, per-student public budget education expenditure in Chongqing's main urban area reached 21,350 yuan, compared with 14,680 yuan in outlying districts and counties overall — a 45.4% gap — and fell below 50% of the main urban figure in the most remote southeastern and northeastern counties. The share of primary and secondary teachers holding a bachelor's degree or above reached 96.8% in the main urban area but remained below 75% in remote mountainous districts and counties. Annual teacher turnover in mountainous areas reached 8.7%, compared with 3.1% in the main urban area — nearly three times higher.

Descriptive results from the survey show all three gap dimensions — policy, resource, and capacity — sitting above the midpoint of the scale, with the resource gap rated most severe (M = 3.91, SD = 0.72), followed by the policy adaptation gap (M = 3.82, SD = 0.69) and the governance capacity gap (M = 3.76, SD = 0.75). All three dimensions correlate significantly and positively with one another: policy gap with resource gap (r = .624, p < .001), policy gap with capacity gap (r = .587, p < .001), and resource gap with capacity gap (r = .603, p < .001). This pattern is consistent with a reinforcing cycle rather than three independent problems: weak policy adaptation, resource shortage, and limited governance capacity move together rather than separately.

The Modified PNI calculation ranks teacher management as the highest-priority domain (priority score 0.782), ahead of educational finance (0.715), school layout (0.623), enrollment (0.541), and educational structure (0.489). Separately, a regression model shows that the degree of alignment between resource allocation and governance capacity — precise matching, in the study's terminology — significantly and positively predicts overall policy implementation effectiveness (β = .527, p < .001), explaining

37.2% of the variance in effectiveness scores. A comparison of implementation strategies further shows that districts pursuing a "priority breakthrough plus coordinated improvement" approach, which concentrates early effort on the highest-ranked domains before addressing lower-ranked ones, achieved implementation effectiveness scores 18.3% higher on average than districts pursuing comprehensive, evenly distributed reform across all five domains simultaneously ($t = 4.21$, $df = 285$, $p < .001$).

None of these results individually proves that teacher retention constrains the other four domains rather than simply outranking them. Taken together, however, they form a coherent pattern consistent with that interpretation. The strong positive correlations among policy, resource, and capacity gaps indicate that these are not independent problems that can be solved in isolation; a shortfall in one compounds the others. Teacher management registers as the largest of these gaps by a wide margin, and it is also the domain most directly tied to governance capacity, since high turnover consumes administrative attention that would otherwise go toward planning and executing reform in other areas — consistent with the personnel-management weaknesses documented elsewhere in China by Xia et al.

(2022) and the teacher-resource-support gap identified by Xue et al. (2021). The finding that hierarchical, priority-sequenced implementation outperforms comprehensive parallel implementation by a substantial margin further supports treating governance reform as a sequencing problem rather than a simple resource-allocation problem: districts that concentrated effort rather than distributing it evenly achieved measurably better outcomes.

This pattern also helps explain why financial investment alone, absent teacher-focused intervention, has produced limited returns in Chongqing's periphery, echoing Xu's (2025) finding that China's equity-oriented Special Programs were substantially blunted by financial constraints even where program design was sound, and Kisanzo et al.'s (2025) broader observation that fiscal equalization and teacher rotation policies underperform their design intent because of unresolved incentive and compensation problems specific to teachers. The parallel finding from Zhou et al. (2025), using the same PNI methodology in a different rural Chinese setting, that human-resource needs consistently rank among the highest-priority gaps, suggests this is not an artifact specific to Chongqing's instrument or sample but a

broader feature of rural and mountainous Chinese education systems.

Policy Implications

For Chongqing specifically, this argues for sequencing municipal transfer payments and special education subsidies toward teacher compensation, rotation infrastructure connecting urban and mountain schools, and reformed promotion pathways for rural-serving teachers, ahead of or at minimum alongside capital investment in school consolidation or facility upgrades. The comparative success of the priority-breakthrough approach over comprehensive parallel reform, documented in Section 5, supports concentrating early-stage reform capacity specifically on teacher retention rather than distributing it evenly across all five domains from the outset. For other mountainous Chinese municipalities facing comparable urban-periphery disparities — and, per J. Li et al. (2022) and Xia et al. (2022), the underlying personnel-policy weaknesses appear to generalize well beyond Chongqing — this suggests that governance-capacity-building initiatives are likely to show limited return where teacher turnover remains unaddressed, and that diagnostic frameworks used to set reform priorities should explicitly test for this kind of cross-domain

dependency rather than treating policy domains as independent.

Limitations

This study's central claim, that teacher retention functions as a binding constraint rather than merely the top-ranked priority, is an interpretation built from the pattern of existing correlational, PNI, and aggregate regression results, not from a newly computed statistical test that formally decomposes implementation effectiveness by domain-specific interaction with teacher turnover. A future analysis using teacher turnover as a moderating variable in domain-specific regression models would provide a more direct test of the sequencing hypothesis proposed here. The data are also cross-sectional and self-reported, limiting causal inference and leaving open the possibility that both teacher turnover and weak implementation in other domains share some common underlying cause, such as overall district fiscal capacity, rather than one directly constraining the other. Finally, the sample is limited to a single municipality; the generalizability of the binding-constraint pattern to other mountainous Chinese cities should be tested directly rather than assumed,

notwithstanding the broader literature reviewed in Section 2 that documents similar teacher-policy weaknesses elsewhere.

4. CONCLUSIONS

Rather than treating teacher management as simply the highest-ranked item among five parallel governance priorities, the evidence assembled here — steep zone-level disparities in teacher qualification and turnover, a Modified PNI ranking placing teacher management first, strong positive interdependence among policy, resource, and capacity gaps, and superior outcomes from priority-sequenced over comprehensive implementation — is consistent with teacher retention functioning as a binding constraint whose resolution disproportionately affects what other reforms can achieve. Read alongside a wider Chinese literature that repeatedly identifies teacher personnel policy as a structurally weak link across otherwise different regional and institutional contexts, this suggests that mountainous municipalities operating under tight fiscal limits have good reason to sequence governance investment around teacher retention first, rather than distributing reform effort evenly across all identified gaps.

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Deepfake Media and Consumer Engagement: An Empirical Study of Social Media Users in Gen Z in China

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ABSTRACT

AI-generated short videos have rapidly become an important form of content on social media platforms, particularly on Douyin (TikTok), where Generation Z users encounter them in everyday online activities. As these videos become increasingly realistic, questions have emerged regarding how users perceive AI-generated content and what motivates them to engage with it. Although existing studies have examined AI-generated media from technological and communication perspectives, the psychological processes underlying consumer engagement remain insufficiently understood. To address this issue, this research combines the Technology Acceptance Model (TAM) with the Stimulus–Organism–Response (S–O–R) framework to explain consumer engagement with AI-generated short videos. Perceived realism, perceived deception, and awareness of AI generation are treated as external stimuli, while cognitive dissonance represents the internal psychological mechanism linking these perceptions to engagement behaviours. Data were collected through a questionnaire survey of 500 Chinese Generation Z users who had experience watching AI-generated short videos on Douyin, and the proposed model was evaluated using structural equation modelling. The analysis demonstrates that perceived realism enhances both cognitive dissonance and consumer engagement, whereas perceived deception reduces both. Awareness of AI generation significantly increases cognitive dissonance but does not directly predict consumer engagement. Instead, its influence operates entirely through cognitive dissonance, highlighting the importance of users' psychological responses when interpreting AI-generated content. Among all examined relationships, cognitive dissonance exerts the strongest positive effect on consumer engagement.

These findings broaden current understanding of how users respond to AI-generated media by identifying cognitive dissonance as a key psychological mechanism connecting AI-related perceptions with engagement behaviours. The results also provide practical guidance for content creators, marketers, and platform operators seeking to balance realism, transparency, and user engagement in AI-generated short-video environments.

Keywords: AI-generated content; Douyin; cognitive dissonance; consumption behavior; Generation Z

1. Introduction

Artificial intelligence (AI) is reshaping the way digital content is produced and consumed across social media platforms. One of the most visible developments is the rapid growth of AI-generated short videos, particularly on Douyin (TikTok), where such content is widely used for entertainment, commercial promotion, and information sharing. For Generation Z, who represent one of the platform's most active user groups, interaction with AI-generated videos has become a routine part of everyday online activity. The growing sophistication of generative AI has made these videos increasingly realistic. This technological progress creates clear advantages by allowing creators and marketers to produce visually appealing content more efficiently. At the same time, it also raises concerns about authenticity. As AI-generated videos become more difficult to distinguish from human-created content, users may find it increasingly challenging to judge whether what they are viewing is genuine. Even when the artificial origin of a video is known, its realistic appearance and entertainment value may still encourage positive reactions, creating a tension between what users know and what they experience. This tension can be understood through cognitive dissonance theory (Festinger, 1957), which argues that psychological discomfort emerges when individuals hold inconsistent cognitions. Within the context of AI-generated short videos, users may simultaneously recognise that content has been created by AI while still perceiving it as realistic, engaging, or enjoyable. Such conflicting evaluations may shape subsequent behavioural responses, including liking, commenting on, and sharing content on social media platforms. Although AI-generated media have attracted increasing academic and industrial

attention, the psychological mechanisms that connect users' perceptions of AI-generated videos with consumer engagement remain insufficiently explored. Addressing this issue is important not only for advancing research on AI-generated media but also for helping content creators, marketers, and platform operators develop engagement strategies that balance innovation, transparency, and user trust.

1.1 Research Questions

RQ1: What are the effects of perceived realism, perceived deception and awareness of AI generation on cognitive dissonance and consumer engagement (likes, comments and shares) when Generation Z users watch AI-generated short videos on Douyin?

RQ2: To what extent does cognitive dissonance mediate the relationships between perceived realism, perceived deception, awareness of AI generation and consumer engagement with AI-generated short videos on Douyin?

1.2 Research Objectives

RO1: To analyse the effects of perceived realism, perceived deception and awareness of AI generation on cognitive dissonance and consumer engagement among Generation Z Douyin users.

RO2: To evaluate the mediating role of cognitive dissonance in the relationships between perceived realism, perceived deception, awareness of AI generation and consumer engagement with AI-generated short videos on Douyin.

1.3 Hypotheses

H1. Perceived realism positively influences cognitive dissonance.

H2. Perceived deception negatively influences cognitive dissonance.

- H3. Awareness of AI generation positively influences cognitive dissonance.
- H4. Perceived realism positively influences consumer engagement.
- H5. Perceived deception negatively influences consumer engagement.
- H6. Awareness of AI generation negatively influences consumer engagement.
- H7. Cognitive dissonance positively influences consumer engagement.

- H8a: Cognitive dissonance significantly mediates the relationship between perceived realism and consumer engagement.
- H8b: Cognitive dissonance significantly mediates the relationship between perceived deception and consumer engagement.
- H8c: Cognitive dissonance significantly mediates the relationship between awareness of AI generation and consumer engagement.

1.4 Conceptual Framework

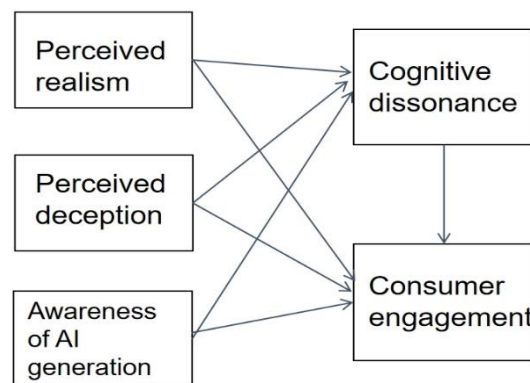


Figure.1 Conceptual Framework

2.1 Literature Reviews

2.1.1 Perceived realism positively influences cognitive dissonance

Perceived realism has long been recognised as an important factor shaping how audiences interpret and respond to media content. Rather than depending solely on visual quality, it reflects users' overall judgement of whether media experiences appear consistent with reality and align with their existing knowledge and expectations (Busselle & Bilandzic, 2008; Cho et al., 2014). When media content is perceived as realistic, users are generally more likely to become

immersed in the experience, develop stronger emotional involvement, and regard the content as credible, all of which encourage deeper cognitive processing (Green & Brock, 2000). The role of perceived realism has become even more significant with the rapid development of generative AI. Advances in AI technology have enabled synthetic videos to achieve increasingly convincing visual quality, natural character movements, and coherent storytelling, making it difficult for many users to distinguish AI-generated content from authentic media. As a result, viewers may

respond to AI-generated short videos in much the same way as they respond to human-created content. However, highly realistic AI-generated videos may also produce conflicting psychological evaluations. A viewer may recognise that a video has been created by artificial intelligence while simultaneously perceiving it as authentic, engaging, and believable. These competing evaluations create inconsistency between technological awareness and subjective experience. From the perspective of cognitive dissonance theory (Festinger, 1957), such inconsistency is likely to generate psychological discomfort because individuals attempt to reconcile two cognitions that are not fully compatible. Within the context of AI-generated short videos on Douyin, greater perceived realism is therefore expected to intensify cognitive dissonance rather than reduce it. As AI-generated content becomes increasingly difficult to distinguish from authentic media, users are more likely to experience tension between what they know about the content's artificial origin and what they perceive during the viewing experience.

2.1.2 Perceived deception negatively influences cognitive dissonance

Perceived deception has become an increasingly important issue in digital media as advances in artificial intelligence make synthetic content more difficult to distinguish from authentic human-created media. Rather

than referring only to false or inaccurate information, perceived deception reflects users' belief that media content is intentionally misleading, manipulative, or conceals its true nature (Darke & Ritchie, 2007). Such perceptions often emerge when the appearance of content conflicts with users' expectations of authenticity and transparency. Within AI-generated media, deceptive cues can substantially influence how users evaluate online content. When audiences suspect that videos have been intentionally designed to create a false impression or disguise their artificial origin, they are more likely to question both the credibility of the content and the intentions of its creator. Previous research has shown that recognising deceptive characteristics encourages more critical information processing, reduces trust, and leads users to adopt defensive evaluation strategies (Vaccari & Chadwick, 2020; Ahmed, 2021). Although deception is generally associated with negative psychological responses, its relationship with cognitive dissonance may differ from that of perceived realism. Cognitive dissonance theory (Festinger, 1957) proposes that psychological discomfort emerges when individuals struggle to reconcile incompatible cognitions. However, when users clearly identify AI-generated content as deceptive, the source of inconsistency becomes easier to explain. Instead of attempting to reconcile conflicting

impressions, they may simply reject the content as untrustworthy and terminate further cognitive processing. In this situation, the ambiguity that normally generates psychological conflict is reduced. Within the context of AI-generated short videos on Douyin, stronger perceptions of deception are therefore expected to weaken cognitive dissonance by encouraging users to form clear negative evaluations at an early stage of information processing. As uncertainty surrounding the authenticity of the content decreases, the psychological tension associated with conflicting perceptions is also likely to diminish.

2.1.3 Awareness of AI generation positively influences cognitive dissonance

As AI-generated content becomes increasingly common on social media platforms, users are becoming more aware that many videos are created or substantially modified by artificial intelligence rather than by human creators. Awareness of AI generation differs from perceived realism and perceived deception because it does not reflect an evaluation of content quality or credibility. Instead, it represents users' recognition of the technological origin of digital media (Vaccari & Chadwick, 2020). Such awareness has gradually become an important factor shaping how audiences interpret and respond to AI-generated content. Existing research suggests that disclosing AI involvement can improve

transparency by informing users about how content is produced. Nevertheless, transparency alone does not necessarily remove uncertainty or eliminate psychological conflict (Shoenberger et al., 2021). When viewers recognise that a highly realistic video has been generated by AI, they may begin to reconsider its authenticity, credibility, and production process. Although the content may remain visually convincing and entertaining, knowledge of its artificial origin can alter the way it is interpreted, resulting in competing cognitive evaluations. This phenomenon can be explained through cognitive dissonance theory (Festinger, 1957). Psychological discomfort arises when individuals simultaneously hold cognitions that are difficult to reconcile. In the context of AI-generated short videos, users may enjoy the realism and entertainment value of a video while also recognising that it is the product of artificial intelligence rather than human creativity. The coexistence of these positive emotional responses and rational awareness creates a conflict between subjective experience and objective knowledge. Within the context of Douyin, where AI-generated short videos increasingly resemble authentic user-created content, awareness of AI generation is therefore expected to intensify cognitive dissonance. As the realism of AI-generated media continues to improve, users are more likely to experience psychological tension when

their favourable viewing experience conflicts with their understanding of the content's artificial origin.

2.1.4 Cognitive dissonance positively influences consumer engagement

Cognitive dissonance has long been recognized as a key psychological mechanism explaining how individuals respond to conflicting information and experiences. Rather than describing a simple negative emotion, it refers to the psychological tension that arises when beliefs, attitudes, or perceptions are inconsistent with one another (Festinger, 1957). To reduce this discomfort, individuals are motivated to restore cognitive consistency by reinterpreting information, adjusting their attitudes, or engaging in behaviours that help resolve the conflict (Harmon-Jones & Mills, 1999). The emergence of AI-generated short videos has created new situations in which cognitive dissonance is likely to occur. Users may recognize that a video has been generated by artificial intelligence while simultaneously perceiving it as visually realistic, entertaining, and engaging. This coexistence of positive emotional responses and rational awareness creates psychological tension, as viewers attempt to reconcile the appealing characteristics of the content with concerns about authenticity, credibility, or manipulation. Importantly, cognitive dissonance does not always lead to

avoidance. In social media environments, psychological tension may instead encourage users to engage more actively with content as they seek to interpret information, express their opinions, or obtain validation from others. Previous studies have shown that interaction behaviours such as liking, commenting on, and sharing content can serve as ways for users to process conflicting perceptions and reduce internal discomfort (Eden et al., 2017; Shin, 2021). Rather than reflecting simple approval of the content, these behaviours may represent attempts to make sense of uncertain or contradictory experiences. This perspective is also consistent with the Stimulus–Organism–Response (S–O–R) framework, in which cognitive dissonance represents the organismic state linking external stimuli with subsequent behavioural responses. Within the context of AI-generated short videos on Douyin, moderate levels of cognitive dissonance are therefore expected to encourage consumer engagement by motivating users to interact with content that evokes both curiosity and psychological conflict.

2.1.5 Perceived realism positively influences consumer engagement

Perceived realism is widely regarded as an important driver of user engagement in digital media environments. When media content appears believable and closely resembles real-life experiences, users are

more likely to become cognitively involved and emotionally connected with what they are viewing (Busselle & Bilandzic, 2008). Rather than simply improving visual appeal, realism strengthens users' sense of presence and encourages them to devote greater attention to the content. A substantial body of research has demonstrated that realistic media experiences promote interactive behaviours across social media platforms. Users who perceive content as authentic and relatable are generally more willing to participate in platform activities, including liking, commenting on, and sharing posts (Hollebeek et al., 2014). This relationship can be explained by the stronger emotional involvement and perceived credibility associated with realistic content. Narrative coherence and visual authenticity further reinforce these responses by making media experiences more immersive and personally meaningful (Hall, 2003; Calder et al., 2009). The same mechanism is expected to operate in AI-generated media. As advances in generative AI continue to improve visual quality and narrative consistency, AI-generated short videos are becoming increasingly capable of delivering viewing experiences that resemble human-created content. Previous studies have likewise reported that realistic virtual characters and AI-generated media are more effective in attracting users' attention and sustaining engagement when they present coherent

and believable experiences (Ho & MacDorman, 2017). Within the context of Douyin, users who perceive AI-generated short videos as realistic are therefore expected to interact with such content more actively. When videos appear authentic, visually appealing, and engaging, users are more likely to express their reactions through platform behaviours such as liking, commenting on, and sharing.

2.1.6 Perceived deception negatively influences consumer engagement

Perceived deception is generally regarded as an important factor that discourages user engagement in digital media environments. When users believe that online content is misleading, manipulative, or intentionally conceals its true purpose, they are less likely to trust the information presented and more likely to distance themselves from the content. Rather than encouraging interaction, perceptions of deception often lead users to evaluate content more cautiously and reduce their willingness to participate in platform activities. Existing research has consistently demonstrated that deceptive communication weakens users' confidence in both content creators and digital platforms, resulting in lower levels of consumer engagement (Essawy et al., 2024). As trust declines, users become less willing to express support for content through public interaction behaviours such as liking,

commenting on, or sharing posts. This tendency is particularly evident on social media, where engagement is visible to others and may influence users' online self-presentation and credibility. The same pattern is expected in the context of AI-generated media. On platforms such as Douyin, users may perceive AI-generated short videos as deceptive when their artificial origin, commercial intent, or persuasive purpose is not clearly disclosed. Previous studies have shown that perceived deception reduces evaluations of authenticity and credibility, leading users to adopt more sceptical attitudes toward synthetic media (Vaccari & Chadwick, 2020; Ahmed & Chua, 2023; Li et al., 2024). As a result, users become less inclined to interact with such content, even when it is visually attractive or entertaining. Within the context of AI-generated short videos on Douyin, stronger perceptions of deception are therefore expected to reduce consumer engagement. As users become increasingly sceptical of the authenticity and intentions behind AI-generated content, they are less likely to express their reactions through behaviours such as liking, commenting on, and sharing.

2.1.7 Awareness of AI generation negatively influences consumer engagement

Whether awareness of AI generation directly affects consumer engagement remains an open question in existing

research. Awareness of AI generation reflects users' recognition that digital content has been created or substantially modified by artificial intelligence, and this knowledge may influence how they evaluate the authenticity, credibility, and novelty of online media. Unlike perceived realism or perceived deception, awareness concerns the origin of the content rather than its perceived quality or trustworthiness. Existing evidence presents inconsistent conclusions regarding the relationship between AI awareness and engagement. Some studies suggest that informing users about AI involvement reduces their willingness to interact with content because disclosure may increase scepticism and lower perceived credibility. This effect is particularly evident in news and deepfake contexts, where AI-generated labels have been shown to discourage content sharing and reduce users' confidence in the information they encounter (Altay et al., 2024; Vaccari & Chadwick, 2020). In contrast, other studies report considerably weaker or even positive effects. Within entertainment-oriented social media environments, AI disclosure often has only a limited influence on users' engagement behaviours because AI-generated content is frequently interpreted as creative, innovative, or technologically interesting rather than deceptive (Li et al., 2024). Users who are more familiar with AI technologies may also regard AI generation as a distinctive

feature that enhances novelty instead of reducing credibility, resulting in relatively neutral or even favourable responses toward AI-generated media (Hingle & Johri, 2024). These contrasting findings suggest that the influence of awareness of AI generation is likely to depend on the communication context and users' expectations. In the context of AI-generated short videos on Douyin, where entertainment value often outweighs concerns about information accuracy, awareness of AI generation may still shape users' engagement behaviours, although the direction and magnitude of this influence remain uncertain

2.1.8 Cognitive dissonance significantly mediates the relationship between perceived realism, perceived deception and awareness of AI generation with on Consumer engagement

The Stimulus–Organism–Response (S–O–R) framework proposes that external stimuli influence behavioural outcomes indirectly through individuals' internal psychological states rather than producing immediate behavioural responses (Mehrabian & Russell, 1974). This perspective provides a useful theoretical foundation for explaining how users respond to AI-generated short videos. Instead of reacting directly to external characteristics such as perceived realism, perceived deception, or awareness of AI generation, users first interpret these stimuli

psychologically before deciding whether to engage with the content. Within this process, cognitive dissonance represents the organismic state that links users' perceptions with their subsequent behavioural responses. When AI-generated short videos evoke conflicting evaluations—for example, when content appears highly realistic despite being recognised as AI-generated, or when users question its authenticity while still finding it entertaining—psychological tension emerges as individuals attempt to reconcile these competing cognitions (Festinger, 1957). The strategies adopted to reduce this tension may subsequently shape users' engagement behaviours, including liking, commenting on, and sharing content. From this perspective, perceived realism, perceived deception, and awareness of AI generation are unlikely to influence consumer engagement independently. Instead, their effects are expected to operate, at least in part, through cognitive dissonance, which translates users' cognitive evaluations into behavioural responses. Based on this theoretical reasoning, cognitive dissonance is expected to mediate the relationships between perceived realism, perceived deception, awareness of AI generation, and consumer engagement

3. Research Methodology

A quantitative research approach was employed to examine the relationships

among perceived realism, perceived deception, awareness of AI generation, cognitive dissonance, and consumer engagement in the context of AI-generated short videos on Douyin. Data were collected through a cross-sectional questionnaire survey involving Chinese Generation Z users, yielding 500 valid responses. This population was selected because Generation Z represents one of the most active user groups on short-video platforms and has extensive exposure to AI-generated content in everyday social media use. The questionnaire consisted of measurement items adapted from well-established scales reported in previous studies.

Minor modifications were made to ensure that the wording accurately reflected the

context of AI-generated short videos on Douyin while preserving the original meaning of each construct.

Responses were recorded using a five-point Likert scale ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree"). Statistical analyses were conducted using SPSS 27.0 and AMOS 27.0. Internal consistency was evaluated using Cronbach's alpha, whereas construct validity was assessed through exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Finally, structural equation modelling (SEM) was applied to test the proposed hypotheses, and bootstrap analysis was performed to examine the mediating effect of cognitive dissonance.

4.Result and discussion

4.1Reliability Test

Table.1 Reliability analysis

Variables	Cronbach's Alpha	Items	Interpretation
Perceived realism	0.863	4	Standard
Perceived deception	0.837	3	Standard
Awareness of AI generation	0.877	4	Standard
Cognitive dissonance	0.836	5	Standard
Consumer engagement	0.849	5	Standard

4.2 Correlation analysis

Table.2 Correlation analysis of variables

	PR	PD	AAI	CD	CE
PR	1				
PD	-0.005	1			
AAI	0.022	0.069	1		
CD	0.250**	0.251**	0.170**	1	
CE	0.234**	0.256**	0.149**	0.420**	1

** . Correlation is significant at the level 0.01 level

4.3 Confirmatory Factor Analysis

Table.3 Structural model fit indices

Fit index	Value	Recommend value	Fit Evaluation
χ^2	200.443		Fit
df	179		Fit
χ^2/df	1.120	<3	Fit
P	0.130	>0.05	Fit
GFI	0.965	>0.9	Fit
RMSEA	0.015	<0.10	Fit
RMR	0.040	<0.05	Fit
CFI	0.995	>0.9	Fit
NFI	0.958	>0.9	Fit
TLI	0.994	>0.9	Fit
PNFI	0.816	>0.5	Fit
PCFI	0.848	>0.5	Fit
SRMR	0.029	<0.1	Fit

Table.4 comparison of competing models

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA	SRMR
Five-factor	200.443	179	1.120	0.995	0.994	0.015	0.029
Four-factor	745.221	183	4.072	0.876	0.858	0.078	0.066
Three-factor	1387.965	186	7.462	0.735	0.701	0.162	0.114
Two-factor	2413.377	188	12.837	0.510	0.452	0.153	0.159
One-factor	3029.813	189	16.031	0.374	0.304	0.173	0.157

4.4 Discrimination validity(HTMT)

Table.5 Discrimination validity

	PR	PD	AAI	CD	CE
PR	-				
PD	0.043	-			
AAI	0.061	0.081	-		
CD	0.289	0.291	0.192	-	
CE	0.255	0.285	0.179	0.489	-

4.5 Convergent Validity and Composite Reliability Test

Table.6 Convergent Validity and Composite Reliability Test

Construct	Item	Factor loading	Cronbach's α	CR	AVE
PR			0.863	0.863	0.612
	PR1	0.799			
	PR2	0.787			
	PR3	0.763			
	PR4	0.780			
PD			0.837	0.837	0.631
	PD1	0.792			
	PD2	0.772			
	PD3	0.818			
AAI			0.877	0.877	0.640
	AAI1	0.807			
	AAI2	0.810			
	AAI3	0.784			
	AAI4	0.798			
CD			0.836	0.836	0.506
	CD1	0.693			
	CD2	0.764			
	CD3	0.696			
	CD4	0.688			
	CD5	0.712			
CE			0.849	0.850	0.531
	CE1	0.699			
	CE2	0.694			
	CE3	0.755			
	CE4	0.750			
	CE5	0.743			

4.6 Main effect test

Table.7 Path coefficients and hypothesis testing

NO.	Path	Standardized β	C.R.	P	Result
H1	PR→CD	0.290	5.626	***	Supported
H2	PD→CD	-0.278	-5.331	***	Supported
H3	AAI→CD	0.163	3.297	***	Supported
H4	PR→CE	0.144	2.883	***	Supported
H5	PD→CE	-0.169	-3.323	***	Supported
H6	AAI→CE	0.090	1.912	0.056	Not Supported
H7	CD→CE	0.381	6.379	***	Supported

Note: *** $p < 0.01$.

The structural model indicates that perceived realism and awareness of AI generation have significant positive effects on cognitive dissonance, whereas perceived deception has a significant negative effect. These findings demonstrate that all three antecedent variables are significantly associated with cognitive dissonance, although the directions of their effects differ. With respect to consumer engagement, perceived realism has a significant positive effect, while perceived deception shows a significant negative effect. By contrast, the

direct effect of awareness of AI generation on consumer engagement is not statistically significant, indicating that Hypothesis 7 is not supported. Among all structural paths, cognitive dissonance exhibits the strongest positive effect on consumer engagement. The structural model also confirms that the proposed relationships are generally consistent with the hypothesised framework, with the exception of the direct path from awareness of AI generation to consumer engagement

4.7 Mediating effect test

Table.8 Mediation analysis results

Hypothesis	Indirect Path	Effect	95% CI Lower	95% CI Upper	P	Result	Mediation Type
H8a	PR→CD→CE	0.111	0.069	0.160	<0.001	Supported	Partial
H8b	PD→CD→CE	-0.106	-0.157	-0.062	<0.001	Supported	Partial
H8c	AAI→CD→CE	0.062	0.025	0.103	0.001	Supported	Full

The mediation analysis demonstrates that cognitive dissonance functions as a significant mediator between users' perceptions of AI-generated short videos and consumer engagement. The indirect effects of perceived realism and perceived deception remain significant, indicating partial mediation because both variables retain significant direct effects on consumer engagement. In contrast, the direct effect of awareness of AI generation on consumer engagement is not significant, whereas its indirect effect through cognitive dissonance is significant, supporting a full mediation effect. Overall, the mediation results indicate that cognitive dissonance plays a significant role in the proposed structural model by transmitting the effects of perceived realism, perceived deception, and awareness of AI generation to consumer engagement.

5.Conclusion

This research investigated how perceived realism, perceived deception, and awareness of AI generation influence consumer

engagement with AI-generated short videos on Douyin by integrating the Stimulus–Organism–Response (S–O–R) framework with the Technology Acceptance Model (TAM). The proposed model demonstrates that users' perceptions of AI-generated content shape engagement not only through direct effects but also through underlying psychological processes.

The empirical findings reveal that perceived realism positively affects both cognitive dissonance and consumer engagement, whereas perceived deception has significant negative effects on both constructs. Although awareness of AI generation increases cognitive dissonance, it does not exert a significant direct influence on consumer engagement. Instead, its effect operates entirely through cognitive dissonance, highlighting the importance of users' psychological responses in translating perceptions of AI-generated content into engagement behaviours.

The findings contribute to the existing literature in several ways. First, they demonstrate that cognitive dissonance provides an effective explanation for how users respond to AI-generated short videos, extending the application of the S-O-R framework to emerging AI-mediated communication contexts. Second, the results suggest that awareness of AI generation should not be viewed as a direct determinant of consumer engagement. Rather, its influence depends on whether awareness creates psychological conflict during the content evaluation process. This perspective offers additional insight into the mechanisms through which AI-related perceptions shape user behaviour.

The study also provides practical implications for content creators, marketers, and platform operators. While realistic AI-generated content can encourage user engagement, maintaining transparency remains equally important for sustaining user trust. Clear disclosure of AI-generated content, together with high-quality visual presentation and coherent storytelling, may help maximise engagement without increasing perceptions of deception.

Several limitations should be acknowledged. The sample consisted exclusively of Chinese Generation Z users on the Douyin platform, which may limit the generalisability of the findings to other cultural settings, age groups, or social media

platforms. Future research could examine the proposed model across different populations and communication contexts. Experimental designs may also be employed to compare different forms of AI-generated content and disclosure strategies, thereby providing a deeper understanding of how users engage with AI-generated media under varying conditions.

Acknowledgement

I would like to express my sincere gratitude to my advisor, Asst.Prof. Tanawat Teepapal, Ph.D. for his continuous guidance, constructive feedback and encouragement throughout the development of this thesis. His academic insight and patient support have been invaluable to my research progress.

My appreciation also goes to the thesis committee members, whose comments and suggestions greatly strengthened the quality and clarity of this study.

I am equally grateful to all the participants who completed the questionnaire, as their willingness to share their experiences and perspectives made this research possible.

Lastly, I would like to thank everyone who has supported me during my study journey. Their understanding and encouragement have helped me complete this work successfully.

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An abstract graphic in the bottom right corner of the page. It features a network of interconnected nodes (small circles) and lines (edges) in shades of blue and purple, creating a sense of digital connectivity or a molecular structure.

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