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Editorial Statement

I, as an editor in chief of International Journal of Industrial Education and Technology (IJIET), would like to welcome and present you Volume 7 number 2, IJIET 7(2), in 2025, which is mainly focuses on industrial education, education and technology. For this IJIET issue, review article is on "ART, CULTURE, AND TECHNOLOGY: RESEARCH PROCESSES FOR INTELLECTUAL VALUE CREATION AND SUSTAINABILITY IN THE AI ERA" and book review is about "DESIGN IN EDUCATIONAL TECHNOLOGY DESIGN THINKING, DESIGN PROCESS, AND THE DESIGN STUDIO". Moreover, over 10 interesting research articles are included for your reading. I would like to invite you to read all the interesting contents authored by the professional and intelligent group of authors to share their outcomes of research and professional discussions. We are welcome to consider the research articles in five sections as Agricultural Education, Environment, and Technology, Architecture and Design Technology, Educational Technology, Engineering and Industrial Technology, and Space Science and Technology. IJIET consists of three contents which are review article, book review, and research articles, respectively

On behalf of the editorial boards, I would like to sincerely delight you with your kind support. If you would like to make comments on this issue to us and give us suggestions regarding on this issue, I would appreciate and sincerely accept that to make things better.

With best regards,

Associate Professor Dr. Prasert Kenpankho, D.Eng.
Editor in Chief
International Journal of Industrial Education and Technology (IJIET)

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ART, CULTURE, AND TECHNOLOGY: RESEARCH PROCESSES FOR INTELLECTUAL VALUE CREATION AND SUSTAINABILITY IN THE AI ERA

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ABSTRACT

This article presents an integrated research approach between "art, culture, and technology" to create intellectual value and sustainability in the era of artificial intelligence (AI). The focus is on conceptual analysis and theoretical frameworks, not empirical experimentation. In the 21st century, technology has become a key factor profoundly transforming human learning and creativity. Therefore, art and culture serve not only as a foundation of identity but also as "cultural-intellectual capital" that can be transformed into knowledge and social value. Thipayasothorn et al. (2024, p. 112) demonstrate that the use of technology in cultural community development projects, such as the "Water Catchment Area - Water Conservation in the East of Bangkok," can tangibly enhance collaborative learning and social sustainability. Furthermore, AI plays a role as a "co-creator," helping to process, analyze, and create new knowledge from artistic and cultural data. The research processes for creating intellectual value thus encompasses exploration, integration, innovation, and reflection. Under the framework of three theoretical concepts: Cultural Capital Theory, Sociotechnical Systems Theory, and Human–AI Co-Creation Theory, which reflect the "three-dimensional balance" of art, culture, and technology, this article concludes that such integrated research is a key mechanism for creating "collaborative intelligence" that promotes the sustainability of human society in the AI era.

Keywords: Art and culture, Integrated research, Intellectual value, AI technology

I. INTRODUCTION

The 21st century is a time when the world is undergoing a full-scale transition from the industrial age to the information age, and into the era of artificial intelligence (AI). This has a direct impact on social, economic, and cultural structures worldwide. Technology has not only transformed work and communication methods, but has also created unprecedented changes in the dimensions of "learning and creativity" (Floridi, 2020, p. 24).

In the context of education and culture, AI technology has become an important tool, enabling humans to create and communicate artistic ideas in new forms. The integration of "art, culture, and technology" is therefore an important trend in contemporary research, aiming to "create intellectual value" and "sustainability" for human society (UNESCO, 2021, p. 33).

Research by Thipayasothorn et al. (2024, p. 112) shows that integrating technology into cultural community development projects, such as "water catchment areas and water conservation," can significantly impact the quality of life of the people. Bangkok-East" can enhance knowledge and create concrete collaboration between educational institutions and communities. It also serves as an example of "using technology to preserve cultural values" that is linked to the concept of urban sustainability. There are shown in Figure 1. Enhancing community life through technology.

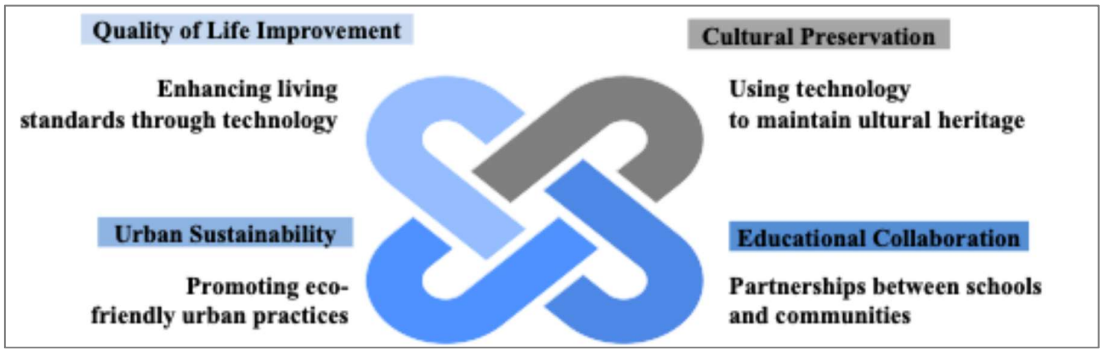

Figure 1: Enhancing community life through technology.

Therefore, this article aims to describe the concept and process of integrated research between art, culture, and technology to create intellectual value and sustainability in the AI era. This paper focuses on conceptual analysis and theoretical frameworks, with less emphasis on empirical experimentation.

II. ARTS AND CULTURE AS CULTURAL-INTELLECTUAL CAPITAL

Brown (2009, p. 59), the concept of "cultural capital" suggests that culture is not merely a social marker, but rather a capital that can be transformed into economic and intellectual value. Art, as a component of culture, thus plays a role as a "mediator of intelligence and identity" that reflects the foundations of communities.

In Thailand, research by Thipayasothorn et al. (2020, p. 65) on the development of mobile phone applications to support urban elderly demonstrates the link between "technology" and "community culture" that promotes participation and self-reliance among older generations. This research serves as an example of the use of cultural capital to create social and intellectual value.

Arts and culture also serve as a value-based data base for AI technologies to learn behavioral patterns, cultural heritage, and create artistic content. For example, using Thai painting image data trains an automated image creation model (Creative AI) for digital preservation (Wang & Lee, 2022, p. 19).

From a process perspective, art and culture are tools for "meaning-making," a core value of human intelligence (Kester, 2013, p. 42). Research in the AI era must be therefore taking an approach that prioritizes value understanding, not just quantitative data as shown in Figure 2.

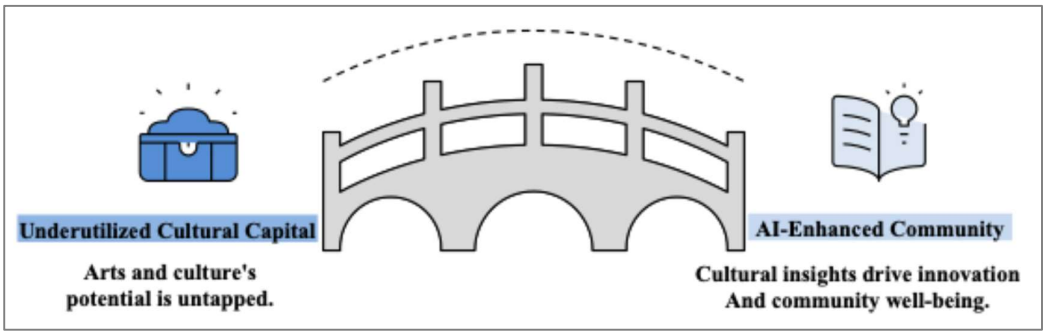

Figure 2: Leveraging arts and culture for AI-driven community development

Arts and culture serve as intellectual capital that reflects the foundations of society and communities, and can be translated into economic value and knowledge. Thipayasothorn et al. (2020, p. 65) research demonstrates the link between technology and community culture to promote collaborative learning. Meanwhile, AI uses art and culture databases to create meaning and value innovation.

III. TECHNOLOGY AND AI AS A VALE CREATION TOOL

AI plays a role as a "co-creator" of humans in the creative and research process (Kaplan & Haenlein, 2022, p. 51). Machine learning and natural language processing technologies enable the automated creation of knowledge that can reflect artistic and social concepts. Thipayasothorn et al. (2023, p. 37) proposed the development of an "application for research standards compliance in higher education institutions," emphasizing the use of digital technology to monitor quality and manage knowledge within institutions. This is an example of "AI for Research Management" that enhances the efficiency of academic knowledge creation.

AI has also been used for cultural analysis, such as using machine vision to classify artifacts or creating 3D cultural reconstructions to preserve virtual historical sites (Craig, 2013, p. 105). Furthermore, the use of chat-based AI expands access to artistic and cultural knowledge for the public.

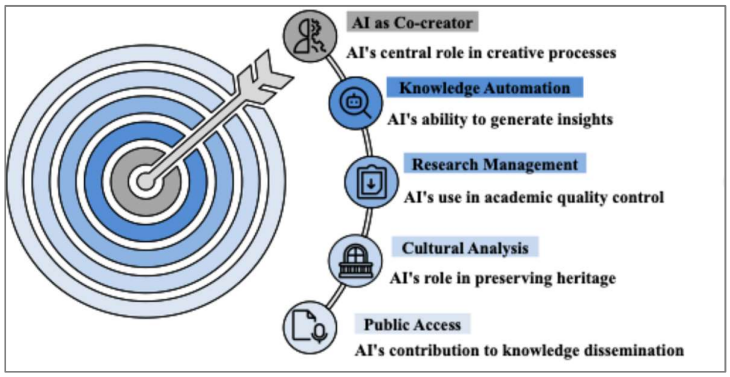

Figure 3: AI in creative and research processes

In social terms as shown of Figure 3, AI enables “collective intelligence” that allows artists, cultural scientists, and scientists to collaborate in digital spaces, particularly in virtual labs where real-time information can be exchanged.

IV. RESEARCH PROCESS FOR INTELLECTUAL VALUE CREATION

Research for intellectual value creation in the AI era emphasizes the integration of knowledge from three main disciplines: art, culture, and technology. This aims to create "collaborative intelligence," which drives society toward sustainability in terms of creativity, economy, and spiritual value. This approach shifts the role of research from a singular knowledge search to a co-creation process of knowledge, in which researchers, communities, and technology collaborate to develop it. The research process for intellectual value creation consists of four main sequential steps: 1) Exploration – Exploring artistic and cultural capital. The first step is to study the artistic and cultural capital available in an area or community to understand the foundations of creativity, values, and local wisdom (Sangdee, 2021, p. 27). This exploration includes the collection of qualitative data, such as traditions, folk art, local design, and the transmission of local stories. These are symbolic capital that can be further developed into creative technologies. 2) Integration – Integrating data on art, culture, and technology. Once cultural data is acquired, the next step is to digitize it so that it can be processed by AI systems, such as scanning artwork, recording folk songs, or creating a community story database. This integration allows for broader access to art and culture, transforming it into a database for machine learning that helps preserve and advance local wisdom in new ways. 3) Innovation – Creating innovations for learning and communication. The third step involves developing tools or technological media to promote cultural learning, such as designing virtual exhibitions, interactive museums, or applications that simulate cultural experiences. These innovations allow users to directly interact with cultural knowledge, fostering both emotional and intellectual learning. 4) Reflection – Reflecting and evaluating intellectual outcomes. The final step is evaluating the research and learning process, using qualitative analysis methods to measure the level of understanding, attitude change, or the development of creative ideas among learners and participants (Suwanachot, 2021, p. 84). This reflection not only measures project effectiveness but also fosters a collaborative learning process (reflective learning) that leads to the continuous development of new knowledge.

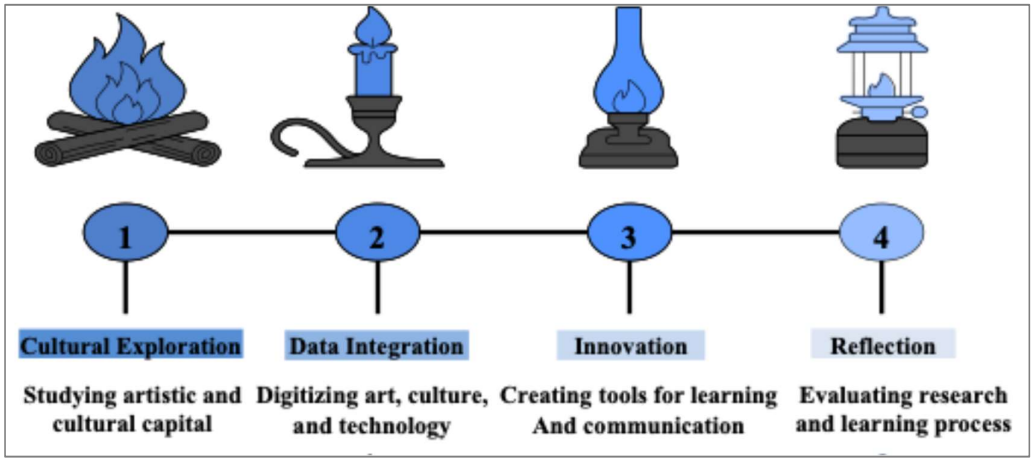

Figure 4: Intellectual value creation in the AI era

As shown in Fig. 4. Intellectual value creation in the AI era, Overall, this four-step process aligns with Zimmerman et al. (2010, p. 45) Research-Based Design (RBD) concept, which emphasizes the use of design processes as part of research, and Chanthep (2023, p. 31) Participatory Action Research (PAR) concept, which allows stakeholders to participate in knowledge creation. This type of research processes therefore it does not only aim to create technological innovation but also aims to create "intellectual value" that connects people, culture, and technology for balanced and sustainable growth.

V. THEORETICLE FRAMEWORK

The theoretical framework of this article aims to explain the relationship between art, culture, and technology through three main theoretical perspectives, reflecting the integration of knowledge to create intellectual value and sustainability in the digital age as shown in Table 1.

Table 1: The theoretical perspectives between art, culture, and technology

No.	Theory / Scholar	Core Concept	Application in Research
1	**Cultural Capital Theory** (Bourdieu, 1986, p. 247)	Culture is an intellectual capital that can be transformed into economic and social value.	Used as a foundation for analyzing Thai cultural capital and transforming it into creative technology.
2	**Sociotechnical Systems Theory** (Trist & Emery, 1951, p. 9)	Technology and society are interrelated and must be developed in balance.	Applied to the design of AI systems that consider cultural and humanitarian contexts.
3	**Human–AI Co-Creation Theory** (Davis, 2019, p. 58)	Humans and AI can collaboratively create knowledge through shared learning.	Used to define research models that allow human–AI co-creation in art and education.

This conceptual framework reflects a "three-dimensional balance" that dynamically integrates art, culture, and technology to create sustainable intellectual value and learning for society. 1) The Artistic Dimension emphasizes the role of beauty and inspiration as creative forces that stimulate imaginative thinking and human emotion. Art is thus a tool for connecting spirituality and innovation. 2) The Cultural Dimension aims to create meaning, identity, and the intellectual roots of society. Culture serves as a reference frame that enables technology to guide development in a way consistent with local contexts and values. 3) The Technological Dimension aims to develop tools and systems that enhance learning, communication, and creativity. Technology expands the reach of art and culture.

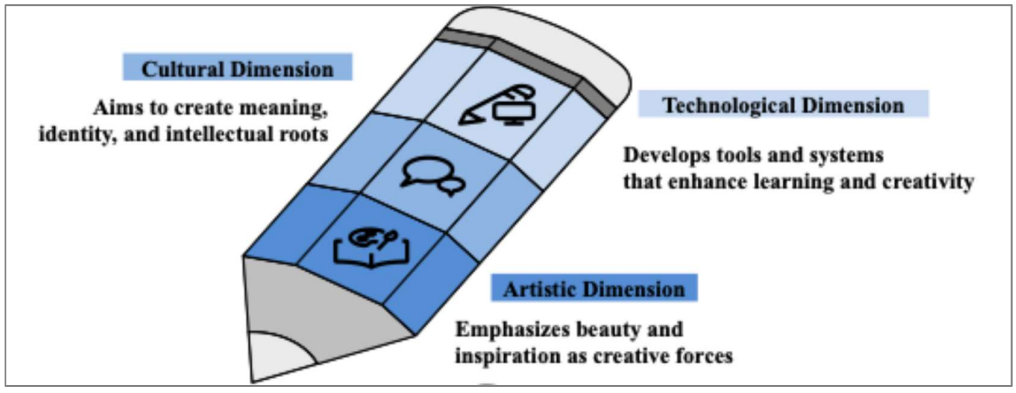

Figure 5: Three-dimensional balance

When all three dimensions are integrated, it leads to the creation of "Collaborative Intelligence," a key driver of human development in the digital age.

VI. CONCLUSION AND RECOMMENDATIONS

Creating intellectual value in the AI era requires recognizing the relationship between art, culture, and technology as the "three pillars of contemporary human intelligence." Integrating these three dimensions not only focuses on developing cutting-edge technologies but also fostering a value-based understanding that reflects the "humanistic spirit" in the digital world (Kara, 2023, p. 33). Policy development guidelines to drive such value are as follows: 1) Educational institutions should establish an Art–Culture–Tech Innovation Lab to integrate cross-disciplinary knowledge between the arts, humanities, and information technology. This serves as a creative space for cultural innovation. 2) Develop "Humanistic AI" that can learn and process from databases of Thai art, literature, and local wisdom to create AI models that understand the subtleties of human culture. 3) Co-creation of learning between humans and technology at the higher education level to enhance design thinking and co-creation of knowledge.

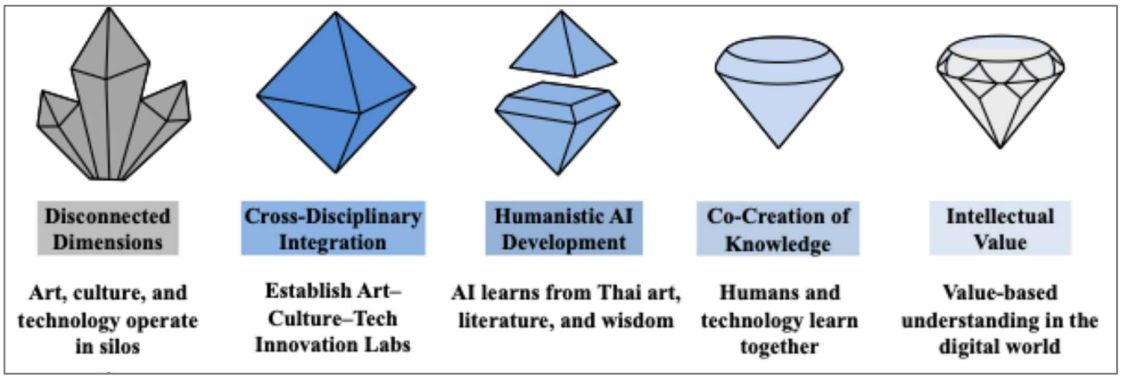

Figure 6: Integrating art, culture, and technology

Policy development guidelines to drive intellectual value in the era of artificial intelligence aim to create a cross-disciplinary learning system integrating art, culture, and technology through the Art–Culture–Tech Lab innovation research center as in Figure 6. This includes developing "humanistic AI" that draws on local wisdom, and promoting co-creative learning between humans and technology in higher education.

In summary, "art, culture, and technology" do not exist in isolation. Rather, they combine to form a collaborative intelligence system that connects humans and the digital environment in a balanced way. Art is the power of imagination, culture is the foundation of values, and technology is the engine of change. When all three come together, they create sustainability across the dimensions of the mind, society, and innovation. This will lead humanity into the AI era with a true understanding and responsibility for the world.

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DESIGN IN EDUCATIONAL TECHNOLOGY DESIGN THINKING, DESIGN PROCESS, AND THE DESIGN STUDIO AUTHORS: BRAD HOKANSON AND ANDREW GIBBONS EDITORS BOOK REVIEW BY THADHARPHUT LIMAPORNVANITR

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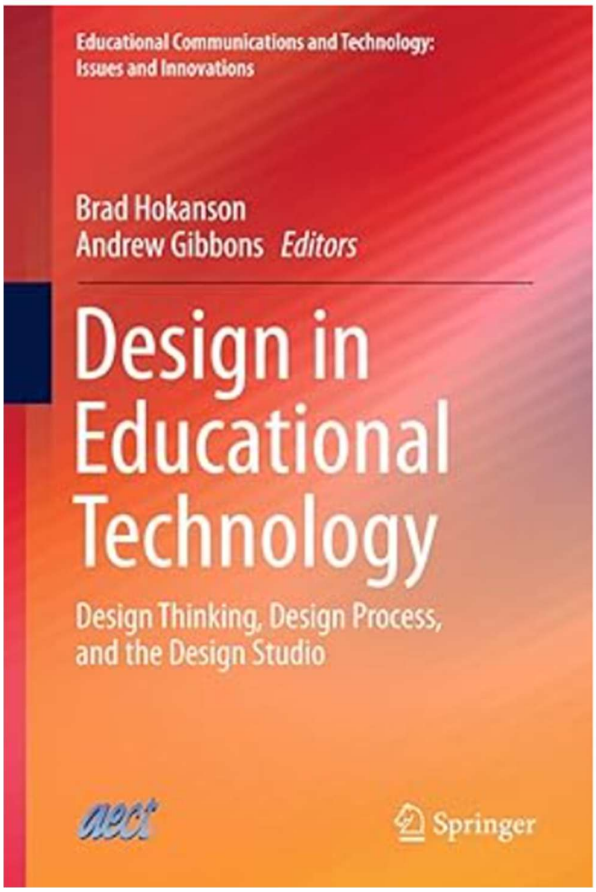

ABSTRACT

This book is the published record of the Association of Educational Communications and Technology (AECT) forum. AECT is a professional association in the area of Educational Technology. The association focus on research of instructional design and business development to enrich teaching and learning within the United States and across the world.
The global studies in educational technology and new applications of recent technologies for learning promote academic research on top of the best practices. This sequence report from the 2012 AECT Summer Research Symposium highlights robust research methodologies used to enhance instructional design in educational technology, specifically focusing on the concept of design thinking. Fifteen full-text articles depicted methodology, process and details of instructional design for the impact of instructional technology.

Keywords: Design thinking, Instructional design, Educational technology

INTRODUCTION

The association members of AECT are found internationally as members of colleges and universities. AECT's research and scholar activities contribute to the knowledge-based instructional design in the field of Learning within the focus of Educational Technology and Curriculum Development. AECT always look for the cutting edge of new developments and innovations in research and application of these areas, the association provides opportunities to raise awareness and leverage technology in education industry through academic activity. An international forum gathers the exchange and dissemination of ideas from associate members and target audiences.

The broad concepts of design form the framework of 2012 AECT Summer Research Symposium that composed with design thinking, design process, and the design studio. First, the adoption of the aspects of design thinking was widespread in range of divergent professions including the field of education. Design Thinking has been considered as future oriented mindset to consider the concept and to realize new things, and it focuses on core process of planning, inventing, making, and doing. Next, design process is a conceptual model to understand critically and to deal with curriculum and educational technology. It is the way to connect theory to the development of educational products. Lastly, Studio-based education is an intrinsic design education, it has been applied for the field of educational technology due to being an effective learning method.

This symposium called for proposals fucus on three components, design thinking, design process, and the design studio, from members of the association, and all proposals evaluated by a panel of experts and the two symposium cochairs. Selected proposal ideas have been developed into full chapters. All authors gathered reviews and revised the chapter draft distribution via the in-person symposium in July 2012. The rich and balanced discussions structured and formed inspired book chapters. The academic viewpoints expressed the view of design to develop articles with authors' best ideas. Open space discussions are the art of hosting movement, exchange views and experiences of authors, participants, experts, and symposium chairs. These processes provide good reflections to improve instructional design. This subsequent publication from design thinking concepts for 2012 symposium brought a new standard to annual conference, It provides a framework for translating educational theory into practical instructional products, ensuring responsible collaboration and a comprehensive understanding of the educational field.

BOOK STRUCTURE

The fifteen chapters discuss various aspects of design and their impact on creating effective curricula. The first chapter illustrates the concept of decision-making processes, reflection-in-action is an element of design thinking approach for instruction design. This approach helps designers to solve the design problem. The next chapter narrates the advanced concepts of instructional design through views of experienced designers. The upcoming chapters talk about studio pedagogy, how instructional design transforms learning environments. Many sides of Design in instructional design, for example, design judgment in instructional design, professional ethics, instructional design processes. The closing chapter compiles key lessons for becoming an effective instructional designer.

REFLECTION

This book develops a deep understanding of the design process, creating readers critical thinking skill. By drawing on traditional design fields and examining the design process, new models of instructional design are generated. These models can then be adapted to bridge principles and practice. A diverse range of empathy fully enhances the goals of education and provides guidance while deepening the foundational knowledge for instructional designers. These emerging topics in this book are practical guidance for readers at all levels. So, it is an ideal book for instructional designers, finding new models of instructional design, and connecting theory to develop a wide range of educational products.

CONCLUSION

All chapters are reported and narrated the past practice to provide opportunities to explore innovative ideas for future instructional design. The editor, Brad Hokanson's background in architecture and his experience in educational technology within academia, believes the useful and supportive design process enhance an innovative educational design with ideas, concepts, and method. This book is a valuable follow-up to the symposium report, offering well-crafted articles and thoughtful insights, the articles are outcomes of a design thinking process, highlighting their innovative and practical nature. An operation of abductive reasoning to transfer thoughts between required purpose and a proper decision. This creates a chore challenge of analysis and synthesis processes and reflects a well-defined and innovative instructional design.

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INTERNATIONAL JOURNAL of Industrial Education and Technology

ORGANIZATIONAL RESILIENCE OF SECONDARY SCHOOLS: A SECOND CONFIRMATORY FACTOR ANALYSIS

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ABSTRACT

This study conducted a confirmatory factor analysis (CFA) of organizational resilience in secondary schools, with findings based on empirical data. The sample for this research consisted of 500 participants, including school directors, deputy directors, and heads of the subject groups from secondary schools, selected through multi-stage random sampling process. The research instrument was a 5-point rating scale questionnaire that underwent content validity verification. The item discrimination indices of the questionnaire ranged from .20 to .80, and the reliability analysis, using Cronbach's alpha coefficient, yielded a value of .92. The statistical method used for data analysis was confirmatory factor analysis (CFA). The study results revealed that organizational resilience in secondary schools comprises four main factors: adaptive capacity, strategic planning, agility, and improvisation. The assessment of the model's goodness-of-fit indices yielded the following results: Chi-Square = .54, RMSEA = .000, GFI = .98, CFI = 1.00, NFI = .99, RMR = .015, RFI = .99, IFI = 1.00, and AGFI = .96, indicating that the model demonstrated congruence with empirical data. The factor loadings of the four main components ranged from .77 to .98, while the factor loadings of the indicators ranged from .38 to .71. The Cronbach's alpha, composite reliability, and average variance extracted values obtained are in the range of .857 – .931, .803 – .924, and .505 – .710, respectively. These values indicated good reliability and acceptable convergent validity. Therefore, developing secondary schools into resilient organizations requires a thorough understanding and integration of key factors influencing organizational resilience to establish internal environments that support personnel and enable effective management of educational resources.

Keywords: Organizational resilience, Adaptability, Strategic planning, Agility, Improvisation

I. INTRODUCTION

The COVID-19 pandemic has triggered a global reset, accompanied by natural disasters such as earthquakes, floods, storms, and fires. These challenges extend beyond natural calamities to include crises and other difficult situations. These circumstances have significantly challenged prevailing assumptions about daily life and work practices (Lazarova et al., 2023, p. 1). Therefore, the concept of organizational resilience is highly relevant to the country, as it enables institutions to respond to crises and unforeseen situations, adapt, and recover from challenging events to ensure long-term survival and success. Educational institutions, which serve as close-knit and formative pillars of society, must undergo adaptive changes to effectively manage and deliver education according to set objectives. School administrators are required to manage education within a new way of life that differs from the past. Consequently, they must implement management practices aligned with the new normal, including preparedness for online teaching through appropriate equipment and technology, curriculum design that considers individual student differences, effective school and teacher management to ensure successful learning outcomes, and physical and mental readiness of both teachers and students (Aytaç, 2020, pp. 57-58).

Studies on organizational resilience have been conducted by scholars and researchers across various contexts, predominantly in the medical and business fields. These studies focus on planning for sudden and unexpected changes to enable organizations to recover from natural disasters, crises, and other challenging situations. Such challenges include shortages of educational resources and personnel, technological advancements, curriculum reforms, changes in instructional management, and the dangers of war. The concept of organizational resilience originated from psychological studies examining children's adaptation in families with schizophrenic parents, which found that only 10 percent of children experienced psychological effects, while the remaining 90 percent could maintain normal lives, with some even achieving academic excellence. This became the starting point for researchers' interest in understanding the psychological processes involved in such responses. The term "Resilience" has begun to be used in Thailand, though studies within educational organizational contexts remain limited, as well as its application across different contexts and sample groups. Research has been conducted in various forms including literature reviews, qualitative and quantitative studies, with data collection from samples in public health organizations, higher education institutions, and business organizations. The statistical methods employed include descriptive statistics, exploratory factor analysis, confirmatory factor analysis, and structural equation modeling. Research findings that can be extended in future studies include measuring resilience among healthcare providers in public health organizations, indicating that healthcare service providers are an appropriate group for studying effective resilient behaviors. The concept of organizational resilience is an emerging framework for understanding and addressing contemporary changes and work-related stress. Resilience helps individuals and organizations develop the capacity to design and implement positive adaptive behaviors in response to specific situations, minimizing stress (Mallak, 1998, pp. 148-152). Organizations' resilience benchmarks are integral for providing recommendations for organizations seeking to build resilience and improve business operations (Stephenson, 2010, p. 3), including the development of

organizational resilience capabilities through human resource management strategies (Lengnick-Hall et al., 2011, p. 243).

In increasingly complex and volatile organizational environments, the concept of organizational resilience has become the new normal. Organizational resilience is a complex, multidimensional concept that emerges from the development of organizational capabilities throughout the organizational life cycle (Evenseth, 2022, p. 1). The challenges and obstacles arising from various changes can be transformed into opportunities for organizational development and educational administration to achieve greater efficiency and effectiveness. Among numerous interesting concepts, Organizational resilience is a notable approach where organizations must plan for and react swiftly and positively to current situations. Simultaneously, it involves progressive planning to transform circumstances and create opportunities for efficient operations (Witmer & Mellinger, 2016, p. 255; Denyer, 2017, p. 5; Khan et al., 2019, pp. 1-26). Organizational resilience represents critical communication for crisis resolution in planning, responding to, and recovering from emergency situations. Furthermore, it can serve as a driving force for both competitive advantage and cultural adaptation. Therefore, organizations must thoroughly understand their internal strengths and weaknesses to effectively implement their strategies and make necessary improvements (Lee et al., 2013, p. 29). Moreover, researchers have identified various components of organizational resilience, including adaptability, strategic planning, agility, and improvisation (Stephenson, 2010, pp. 10-15; Lee et al., 2013, pp. 29-41; Lengnick-Hall et al., 2011, pp. 243-255; Madi-Odeh et al., 2023, pp. 440-468). The basic education curriculum for students at different developmental stages emphasizes distinct focal points. At the secondary school level, the curriculum focuses on enabling learners to explore their aptitudes and interests, develop critical, creative, and problem-solving thinking skills, acquire life skills, and utilize technology as a tool for learning. It also aims to cultivate social responsibility, foster a balanced development of knowledge, morality, and values, and provide a foundation for future careers or further education. Consequently, any disruption in the provision of education at the secondary level may adversely affect students' long-term educational outcomes. Based on the identified components of organizational resilience, the researcher applies these elements to enhance the development of both the organization and its personnel, ensuring effective operation and progress in rapidly changing environments. This approach not only enables the organization to respond effectively to challenges but also to move forward with stability and confidence.

Therefore, the researcher is interested in examining the components of organizational resilience in secondary schools to develop a model appropriate for educational institutions. This model would serve as a framework for administrators and management teams to apply or adapt as guidelines for enhancing educational administration quality, amid rapidly changing and potentially severe circumstances that may arise at any moment.

II. LITERATURE REVIEW

Organizational resilience must necessarily establish objectives or goals for implementation, employing diverse methodological approaches. A primary responsibility of leaders is to help personnel understand the nature of natural disasters, crises, and challenges facing the organization, and to identify appropriate response strategies. Therefore, it is essential for leaders to be knowledgeable about the components of organizational resilience in order to develop frameworks that guide school administrators in considering the factors influencing the resilience of their institutions. This understanding is crucial for effectively developing schools into resilient organizations capable of adapting to all situations and changes. Leaders should implement rigorous management strategies that are both defensive and progressive, applied consistently yet flexibly. Organizational resilience requires continuous effort, as neglecting any single aspect may lead the organization toward disaster (Denyer, 2017, p. 5). From studies of organizational resilience components, scholars and researchers have examined and presented these components from varying perspectives. Based on the component analyses conducted by Stephenson (2010, pp. 10-15), Lee et al. (2013, pp. 29-41), Lengnick-Hall et al. (2011, pp. 243-255), and Madi-Odeh et al. (2023, pp. 440-468), it can be concluded that organizational resilience comprises four essential components: Adaptability, Strategic planning, Agility, and Improvisation.

Adaptability refers to an individual's capacity to manage physical and psychological problems and obstacles in alignment with changing environmental conditions. This includes learning new tasks and work methodologies, maintaining positive interpersonal relationships with others, and utilizing technology proficiently to achieve organizational objectives. It encompasses maintaining an open mind, accepting reality, and viewing situations from multiple perspectives in preparation for unexpected events. Strategic planning refers to the process of analyzing and forecasting the future to establish appropriate approaches for achieving organizational goals. This involves analyzing both internal and external organizational environments to identify strengths, weaknesses, opportunities, and threats. It encompasses the ability to formulate clear vision, mission, objectives, and strategies, accompanied by continuous monitoring and evaluation. Agility refers to an organization's capacity to adapt and respond to changes rapidly and efficiently, employing strategies to enhance personnel work skills and enabling staff to implement new concepts to achieve organizational objectives. Improvisation refers to the process where personnel employ their creativity and specialized skills to manage and solve problems in unexpected situations. This is expressed through immediate responses characterized by flexibility, with the aim of achieving optimal results tailored to each circumstance, all while maintaining organizational protocols. Given the focus on examining the components of organizational resilience, confirmatory factor analysis (CFA) was employed to analyze the relationships between variables and the theoretically derived components, particularly to assess the validity of the model. This involved evaluating the model’s goodness-of-fit with empirical data using established fit indices, as well as assessing the model’s reliability by examining the construct reliability (CR) of latent variables and the average variance extracted (AVE).

III. RESEARCH METHODOLOGY

The purpose of this research was to conduct a confirmatory factor analysis (CFA) of organizational resilience in secondary schools.

A. Participants

The research sample consisted of 500 participants, including principals, deputy principals, and heads of the subject groups in secondary schools. The sample size was determined according to the criteria established by Tabachnick and Fidell (2012, p. 618), which recommend that a sample size of 500 for confirmatory factor analysis (CFA) is considered excellent. A multi-stage sampling process was employed as follows: 1) A stratified random sampling method was employed by categorizing the sample according to school size, namely small, medium, large, and extra-large secondary schools. The proportion of samples for the study was then determined in alignment with the proportion of each school size. For each selected secondary school, the sample comprised one school director, four deputy directors, and five heads of the subject groups; and 2) simple random sampling was applied to select schools from each size category, resulting in a total sample of 500 participants.

B. Variables

The variables are the dimensions of organizational resilience, as shown in Figure 1, and include: 1) Adaptability, 2) Strategic planning, 3) Agility, and 4) Improvisation.

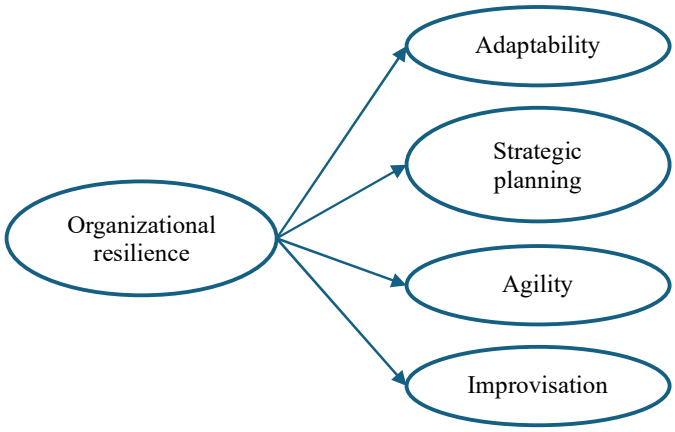

Figure 1: The dimensions of organizational resilience

C. Research Instrument

This study employed quantitative research methodology to examine perceptions of organizational resilience in secondary schools. The researcher developed a questionnaire based on the conceptual framework derived from a review of the literature, which was subsequently validated by five experts to assess content validity. The results were analyzed to determine the item-objective congruence (IOC) index, with values ranging from .6 to .8 for the questionnaire items used in this research. The questionnaire was then piloted with 30 participants (a try-out group) including school principals, deputy principals, and heads of the subject groups from secondary schools who were not part of the main research sample. The data were analyzed for discriminatory power using Pearson's simple correlation method by calculating the item-total correlation. The analysis revealed discrimination values ranged from .28 to .80, meeting the

established criteria (Ebel, 1976, p. 128). Reliability analysis using Cronbach's alpha coefficient yielded an overall reliability of .92. The reliability coefficients for the individual dimensions were: agility (.(66, adaptability (.(76, strategic planning (.(94, and improvisation (..(85

The research questionnaire was administered through an online platform using google forms. The research instrument was a structured questionnaire employing a five-point Likert scale, with response options ranging from 5 (strongly agree) to 1 (strongly disagree). The procedure for constructing a research questionnaire are presented in Figure 2.

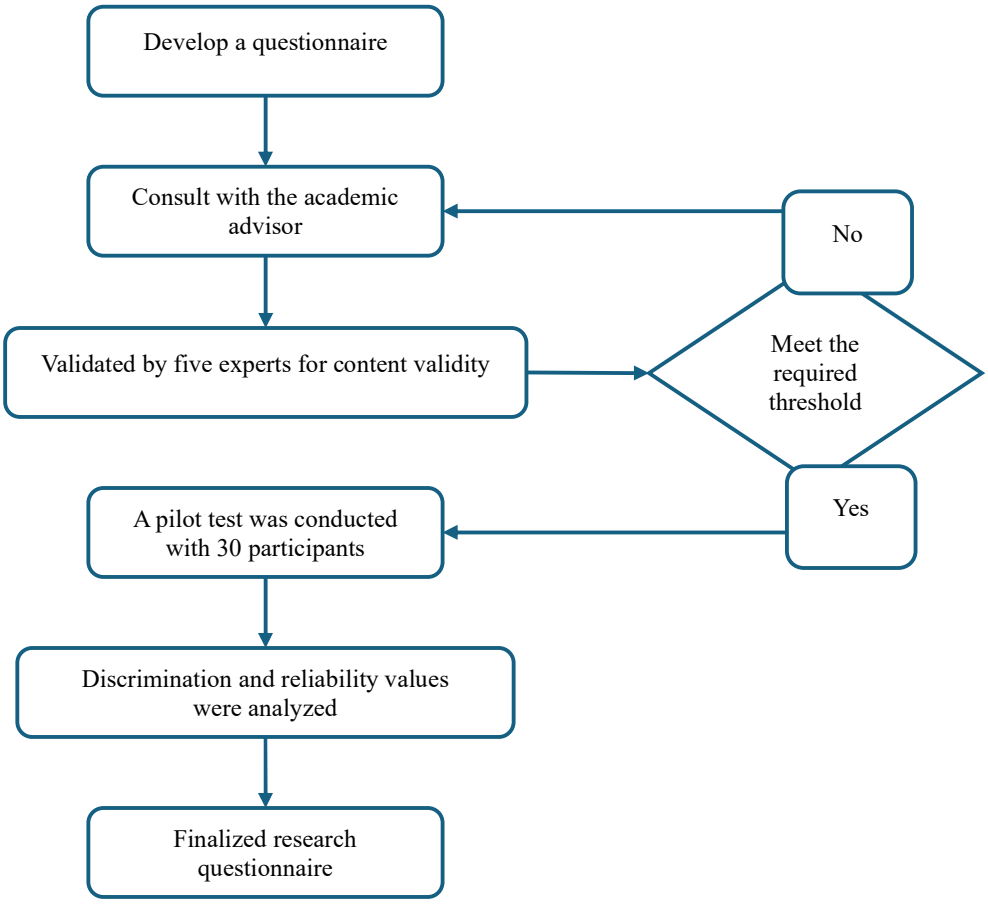

Figure 2: The procedure for constructing a research questionnaire

D. Data Analysis

The researcher analyzed data using statistical software to process the data, calculate means, standard deviations, and perform second-order confirmatory factor analysis to examine the congruence between questionnaire items and objectives. The analysis included evaluation of the Goodness-of-Fit Index according to criteria established by Hair et al. (2010, pp. 639-644).

IV. RESULTS

Prior to analysis, the researcher verified preliminary assumptions for analyzing variable relationships, including examination of the Kaiser-Meyer-Olkin measure (KMO) to assess the suitability of the entire dataset for analysis. According to Hair et al. (2010, p. 104), the KMO value should exceed .5. The KMO value obtained from this analysis was .947. Additionally, Bartlett's Test of Sphericity was conducted to examine the overall relationships among variables, which, according to goodness-of-fit criteria, must be statistically significant (p-value < .05), indicating that the variables are sufficiently correlated to proceed with factor analysis.

The examination of the Goodness-of-Fit Index using Confirmatory Factor Analysis (CFA) indicated that the model demonstrated an acceptable fit to the empirical data (Chi-Square = .54, RMSEA = .000, GFI = .98, CFI = 1.00, NFI = .99, RMR = .015, RFI = .99, IFI = 1.00, and AGFI = .96, Sisan, 2017, p. 863), As shown in Table 1, these results indicate congruence of the second-order confirmatory factor analysis measurement model for organizational resilience variables with the empirical data.

Table 1: Summary of fit indices

Index name	Index value	Accepted value	Status
Chi-Square	.54	$p \geq .05$	Fit
RMSEA	.000	$<.05$	Fit
GFI	.98	$>.90$	Fit
CFI	1.00	$>.95$	Fit
NFI	.99	$>.95$	Fit
RMR	.015	$<.80$	Fit
RFI	.99	0 – 1	Fit
IFI	1.00	$>.90$	Fit
AGFI	.96	$>.90$	Fit

The results of the data analysis revealed that organizational resilience in secondary schools comprises four main factors: Adaptability (six indicators), Strategic planning (five indicators), Agility (four indicators), and Improvisation (five indicators). The findings from the second-order confirmatory factor analysis of organizational resilience in secondary schools indicate that all factor loadings exceeded the threshold value of .30 (Hair et al., 2010, p. 116). The factor loadings for the four latent constructs ranged from .77 to .98, with corresponding reliability coefficients ranging from .66 to .95." Then, for each factor: "Agility exhibited the highest reliability, with indicator factor loadings ranging from .42 – .53 and corresponding reliability coefficients ranging from .45 – .60. Adaptability showed factor loadings of indicators ranging from .38 – .51, with reliability ranging from .40 – .54. Strategic planning had factor loadings of indicators ranging from .56 – .71, with reliability values ranging from .58 – .90. Improvisation exhibited indicator factor loadings ranging from .51 – .55, with reliability ranging from .58 – .68. The detailed results of the data analysis are presented in Table 2 and Figure 3.

Table 2: Result of second confirmatory factor model analysis of organizational resilience of secondary schools

Organizational Resilience (OR)	$\bar{x}$	SD	Factor Loading	Standardize Error	t	R^2
Adaptability (OR1)	**4.36**	**.508**	**.90**	**.06**	**15.28**	**.81**
OR1.1 Personnel are capable of coping with physical and psychological challenges and obstacles.	4.29	.686	.48	-	-	.50
OR1.2 Personnel are able to learn and perform new tasks beyond their assigned responsibilities.	4.36	.687	.46	.03	16.09	.45
OR1.3 Personnel demonstrate good interpersonal relationships with others.	4.52	.592	.38	.03	12.82	.40
OR1.4 Personnel are proficient in utilizing technology effectively.	4.34	.643	.44	.03	13.31	.47
OR1.5 Personnel are open-minded and willing to accept unexpected events or realities.	4.30	.701	.51	.04	14.59	.54
OR1.6 Personnel are able to assess situations from multiple perspectives.	4.35	.676	.49	.03	14.37	.53
Strategic planning (OR2)	**4.39**	**.648**	**.77**	**.05**	**16.55**	**.60**
OR2.1 School administrators establish appropriate directions for the institution.	4.39	.697	.59	-	-	.73
OR2.2 School administrators conduct analyses of strengths, weaknesses, opportunities, and threats (SWOT) in planning for school development.	4.36	.740	.56	.03	21.00	.58
OR2.3 School administrators define a clear vision, mission, goals, and strategic plans.	4.45	.743	.60	.03	18.59	.66
OR2.4 School administrators regularly monitor and evaluate operational performance.	4.41	.731	.60	.03	20.24	.68
OR2.5 School administrators effectively adapt strategies in response to changing circumstances.	4.36	.753	.71	.03	25.25	.90
Agility (OR3)	**4.38**	**.563**	**.98**	**.06**	**15.32**	**.95**
OR3.1 The school is able to adapt to various changes.	4.49	.622	.42	-	-	.45
OR3.2 The school can respond to changes quickly and efficiently.	4.38	.663	.49	.03	18.38	.54
OR3.3 The school utilizes strategies to enhance the work skills of its personnel.	4.33	.690	.50	.03	15.23	.52
OR3.4 Personnel are able to apply new conceptual frameworks to achieve organizational goals.	4.34	.683	.53	.04	14.43	.60

Table 2: (Continued) Result of second confirmatory factor model analysis of organizational resilience of secondary schools

Organizational Resilience (OR)	$\bar{x}$	SD	Factor Loading	Standardize Error	t	R^2
Improvisation (OR4)	**4.37**	**.563**	**.80**	**.05**	**15.65**	**.64**
OR4.1 Personnel are able to apply creative thinking in resolving various situations.	4.36	.667	.52	-	-	.61
OR4.2 Personnel can utilize their unique skills to manage unexpected situations.	4.35	.676	.55	.03	19.00	.68
OR4.3 Personnel demonstrate flexibility in problem-solving.	4.43	.649	.51	.03	16.72	.62
OR4.4 Personnel can effectively resolve issues using intuition.	4.33	.683	.52	.03	17.53	.59
OR4.5 Personnel manage crisis situations while maintaining order within the institution.	4.37	.678	.52	.03	17.21	.58

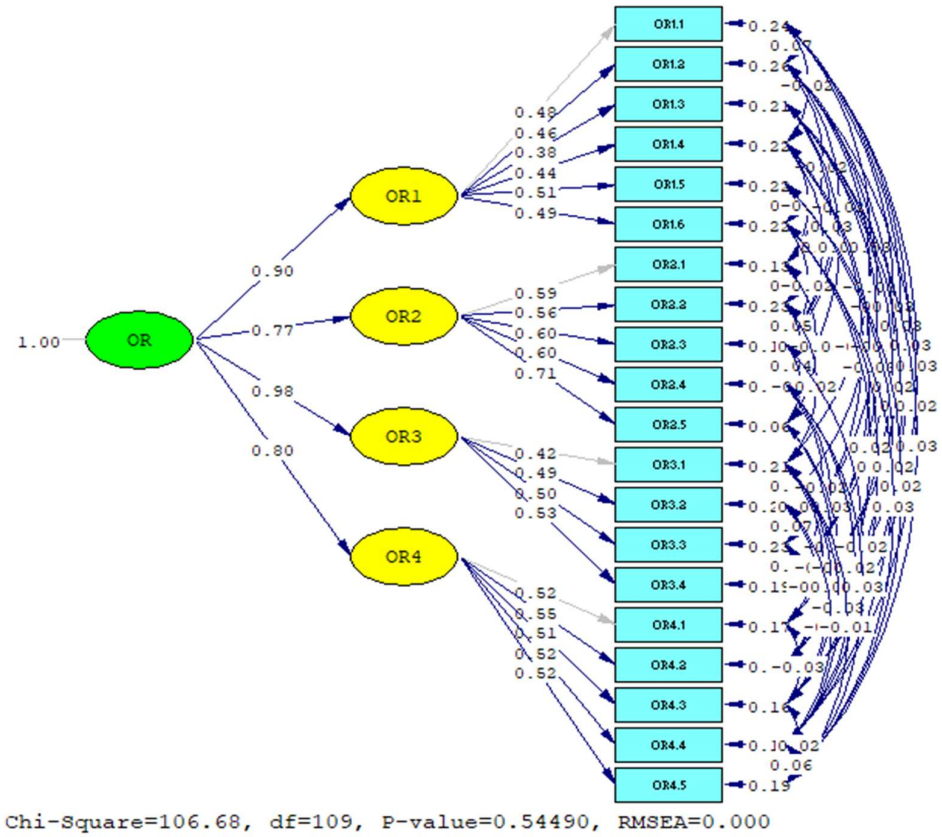

Figure 3: Results of the second confirmatory factor model analysis of secondary schools

The measurement model assessment was conducted through confirmatory factor analysis (CFA), as presented in Table 3. The reliability analysis employed Cronbach's alpha coefficient (α), which should exceed .7, composite reliability (CR), which should exceed .6, and average variance extracted (AVE), which should exceed .5 (Hair et al., 2010, p. 91). The Cronbach's alpha values obtained were in the range of .857 – .931, composite reliability (CR) values were in the range of .803 – .924, and average variance extracted (AVE) values were in the range of .505 – .710. This indicated good reliability and acceptable convergence.

Table 3: Results of the measurement model

Construct	α	CR	AVE
Adaptability (OR1)	*.857*	*.803*	*.505*
Strategic planning (OR2)	*.931*	*.924*	*.710*
Agility (OR3)	*.869*	*.817*	*.527*
Improvisation (OR4)	*.896*	*.869*	*.623*

V. CONCLUSION AND DISCUSSION

The confirmatory factor analysis model of organizational resilience in secondary schools examined in this research study revealed that organizational resilience comprises four main components: Adaptability, Strategic planning, Agility, and Improvisation. The evaluation of the model's Goodness-of-Fit indices yielded the following results: Chi-Square = .54, RMSEA = .000, GFI = .98, CFI = 1.00, NFI = .99, RMR = .015, RFI = .99, IFI = 1.00, and AGFI = .96, indicating that the model demonstrates congruence with the empirical data. The factor loadings of the four main components ranged from .77 to .98, while the factor loadings of the indicators ranged from .38 to .71. The Cronbach's alpha, CR, and AVE values obtained were in the range of .931. - 857, .924. - 803, and .710. - 505, respectively, demonstrating good reliability and acceptable convergence. Therefore, developing secondary schools into resilient organizations requires a thorough understanding and integration of key factors influencing organizational resilience to establish internal environments that support personnel and enable effective management of educational resources.

The first component, adaptability, aligns with the work of Lengnick-Hall et al. (2011, p. 243), Madi-Odeh et al. (2021, p. 11), Stephenson (2010, p. 174), and Lee et al. (2013, p. 34), which describes the capacity to restore appropriate conditions in response to changing environments. Individual adaptability across various change scenarios is essential for organizations aspiring to achieve professional success. The rationale behind adaptation to change stems from the understanding that personnel experiencing personal difficulties will demonstrate reduced effectiveness, particularly during the initial phases of change when productivity often diminishes significantly. Individuals with strong adaptive capabilities typically exhibit analytical and creative thinking skills, remain receptive to acquiring diverse new knowledge, can organize their cognitive processes to respond effectively to work demands, are prepared to manage risks and consistently experiment with novel approaches, and crucially, can regulate their emotions, maintain optimistic perspectives, and interact harmoniously with others. The second component, strategic planning, corresponds with the work of Stephenson (2010, p. 174), Madi-Odeh et al. (2021, p. 11), and Lee et al. (2013, p. 34). Strategic planning constitutes an effective organizational development process that provides operational guidelines with the capacity for potential development

and adaptability to contemporary organizational changes. Thrugh strategic planning, administrators can investigate problems and evaluate the organization's status, resulting in clearly defined organizational goals and operational directions. This process facilitates alignment and enhances organizational workflow efficiency. Additionally, it helps the organization establish a clear vision that all members can understand and embrace. The third component, agility, aligns with Lengnick-Hall et al. (2011, p. 243), wherein agility refers to organizational nimbleness with primary emphasis on people and internal systems that must operate at speeds commensurate with competitive conditions and environmental changes. Agile organizations can move or advance rapidly (Handscomb et al., 2020, pp. 1-7). The characteristics of agility include the capacity to perform beyond planned parameters, develop personnel skills for future requirements, grant autonomy to organizational members while facilitating collaborative work, establish shared work objectives, implement expeditious decision-making processes, convene meetings only when necessary, and prioritize the creation of practical operational processes rather than documentation-based performance evaluation. The fourth component, improvisation, corresponds with Lengnick-Hall et al. (2011, p. 243), reflecting how organizations have transitioned from traditional personnel management approaches to new methodologies appropriate for rapid change, characterized by swift responsiveness, flexibility, unplanned innovation, and sustainable organizational development, thereby enhancing organizational crisis management capabilities (Altarawneh, 2024, p. 42). This concurs with Alhamdany et al. (2023, p. 399), who identify improvisation as spontaneous and creative action where experienced individuals respond to threats utilizing available resources within constrained timeframes. Improvisation enables organizations to adapt efficiently to changing conditions and events while enhancing flexibility and the capacity to respond effectively and promptly to unexpected situations. Consequently, developing secondary schools into resilient organizations necessitates factors that influence organizational resilience to facilitate appropriate internal secondary school environments regarding both personnel and efficient educational resource management. Therefore, developing secondary schools into resilient organizations necessitates a thorough understanding of the components of organizational resilience and fostering among school personnel the components of adaptability, agility, and improvisation. Possessing these three components enables personnel to respond swiftly and effectively to sudden changes or to any strategic direction pursued by school administrators. Furthermore, administrators must take the lead in strategic planning and actively involve personnel in the planning process to foster a sense of ownership and commitment to their work. Understanding the components of organizational resilience also facilitates the precise identification of factors influencing resilience, which in turn can promote and support the creation of an optimal internal school environment, both in terms of personnel and the effective management of educational resources.

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THE EFFECTS OF USING PROBLEM-BASED LEARNING TO PROMOTE INNOVATIVE THINKING SKILLS

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ABSTRACT

This study aimed (1) to compare the learning achievement of third-year Public Administration students at Prince of Songkla University, Surat Thani Campus, in the topic of public service design and transformation in the digital era before and after the implementation of Problem-Based Learning (PBL), and (2) to examine the development of their innovative thinking skills. The participants were 177 third-year students enrolled in the "Digital Civil Servant Competency Development" course during the first semester of the 2024 academic year. The research instruments included a PBL-based instructional plan, a learning achievement test on designing public services and new public sector operations using digital technology, comprising four essay questions (IOC = 0.82, difficulty = 0.68, IDisc> 0.30), an innovative thinking assessment form covering six aspects—interpretation, generate, collaboration, reflect, representation, and evaluation—using a five-point rating scale (IOC = 0.85), and a rubric for evaluating digital public service design. Data were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (paired sample t-test). The results showed that post-intervention learning achievement scores were significantly higher than pre-intervention scores at the .05 significance level. Furthermore, students demonstrated a statistically significant improvement in innovative thinking skills, the mean differences across dimensions ranged from 2.10 to 2.65, with correspondingly high t-values (25.40–37.11) and very large effect sizes (Cohen's d ≈ 1.91–2.79). Evaluation of group projects revealed that 42.86 percentage (15 out of 35 groups) achieved a high level of performance in designing digital public services. These findings suggest that problem-based learning is an effective pedagogical approach for fostering innovative thinking and enhancing digital competencies among public administration students, thereby contributing to the capacity building of future civil servants in the digital era.

Keywords: Innovative thinking, Problem-based learning, Public administration students, Digital public service, Higher education

I. INTRODUCTION

The dawn of the Fourth Industrial Revolution, coinciding with the onset of globalization and the transition into the 21st century, has been marked by the pervasive integration of Artificial Intelligence (AI) technologies, the proliferation of data, and profound lifestyle shifts (Sepriyanti et al., 2021, p. 314). While Industry 4.0 is still in its early stages, many industry leaders and technology experts are already anticipating the imminent emergence of Industry 5.0 (Mourtzis, 2021, p. 7). In this rapidly evolving global landscape, one of the most critical demands of the 21st century is the cultivation of a highly skilled workforce-one nurtured by effectively managed educational institutions capable of addressing new challenges and achieving improved outcomes (Ramirez, 2018, p. 1). Contemporary employment increasingly requires individuals who are proficient in operating, producing, and managing new information using advanced technologies. Consequently, educational institutions play a pivotal role in equipping students with the essential thinking skills required in both present and future work environments, particularly by fostering innovative thinking (Miterianifa, 2021, p. 30). The education system thus serves not only as a bridge connecting labor market demands with learning programs but also as a vital mechanism for preparing learners to function effectively within dynamic and diverse workplaces (Khan et al., 2019, p. 223).

The Partnership for 21 st-century Skills (P21 Framework), developed through collaboration among educators, education experts, and business leaders, defines and illustrates the knowledge, skills, expertise, and support systems students need to succeed in work, life, and citizenship (Partnership for 21st Century Skills, 2011, p. 5). This framework continues to be employed by thousands of educators and hundreds of schools both nationally and internationally to place 21st-century skills at the heart of teaching and learning. Each component of the framework is essential to ensuring students are prepared for the demands of the modern world. When schools, districts, or states build this foundation by integrating core knowledge and skills with key support systems-such as standards, assessments, curriculum and instruction, professional development, and learning environments - students become more engaged in the learning process and graduate prepared to thrive in today's digitally interconnected and globalized society (Partnership for 21st Century Skills, 2011, p. 5). Project-Based Learning (PBL) stands out as an instructional and curricular approach that empowers students to develop practical solutions by integrating theory and practice, conducting research, and applying acquired knowledge and skills (Rosenbaum et al., 2015, p. 183). This strategy promotes active and engaged learning, encouraging students to take ownership of their educational journey. Well-designed PBL projects enable students to cultivate essential skills such as teamwork, project management and leadership, communication (oral and written), self-awareness, group process evaluation, independent learning, critical thinking and analysis, concept explanation, self-directed learning, application of core content to real-world scenarios, research, data utilization, and cross-disciplinary problem-solving (Nilson, 2010, p. 187).

Problem-Based Learning (PBL) is widely regarded as an effective pedagogical method for fostering innovative thinking skills. It immerses students in real-world problem-solving within complex environments where solutions are not readily available in textbooks. This instructional approach not only enhances critical and creative thinking but also prepares students to navigate the challenges of future work settings by developing adaptable, innovative mindsets.

Given this background and significance, the development of innovative thinking skills is crucial in preparing the workforce for an era characterized by technological change and evolving demands. This aligns with the curriculum development mission of the Public Administration Program at Prince of Songkla University, Surat Thani Campus, which explicitly states in its Program Learning Outcome (PLO2) that students should be able to analyze and create innovations for public administration and affairs appropriately. The Digital Competency Development for Civil Servants course, therefore, plays a vital role in fostering this competency through the design of learning processes conducive to the cultivation of innovative skills. The application of Problem-Based Learning (PBL) is a key approach that provides students with opportunities to develop both content knowledge and the necessary skills for working in the digital age. This will help prepare them to become public sector managers capable of improving internal operations and enhancing the agility of public services. Innovation in the public sector is essential for elevating the quality of services and increasing the efficiency of government agencies in the future. Therefore, this research aims to investigate the impact of problem-based learning on the development of innovative thinking skills, with the research objectives being to compare learning achievement regarding the design of new digital public services and operations before and after PBL implementation and to examine students' innovative thinking skills resulting from PBL in the context of designing digital public services. These studies will equip students with the necessary skills to design new public services and management approaches that are responsive to technological changes and societal needs, thereby enhancing the quality and efficiency of public service delivery in the future. Additionally, the research findings will contribute to evaluating the effectiveness of PBL in teaching and developing innovative thinking skills and will provide data for refining instructional practices for greater efficiency, ultimately preparing students to work effectively in the digital public sector.

II. LITERATURE REVIEW

The development of innovative thinking skills has become a key objective in learning management in the digital age, particularly for learners who play a vital role in driving social and public sector advancement. Research by Rengrad et al. (2022, pp. 338–354) examined strategies for organizing learning activities that foster innovative thinking among junior high school students. The study found that designing activities connected to real-life contexts and learners' personal experiences - such as using hypothetical situations aligned with students' interests and encouraging teamwork- positively influences the development of creative and innovative thinking. Similarly, research by Meenongwah et al. (2020, pp. 295-307), which focused on nursing students, revealed that while educators acknowledged the importance of cultivating health innovators, they faced challenges related to confidence, instructional management, and

resource constraints. This highlights the need to enhance teacher competencies to improve innovation-oriented learning in higher education. In the area of systematic learning model development, Thongthiya et al. (2024, pp. 107-119) introduced a "learning management model based on transformative learning concepts with design thinking," known as the 5D Model (Define, Discover, Discuss, Develop, Diversify). The study showed that this model effectively promotes innovative thinking in students studying to become teachers and can be adapted for use with students in other academic fields as well. At the public sector level, research by Dechpaeng et al. (2022, pp. 706-719) found that knowledge exchange between new and old generation civil servants is an important mechanism that helps reduce the gap in thinking. And promote collaborative learning in the public sector. In addition, good relationships between colleagues and supervisors are also factors that contribute to creating innovation in the context of public administration. And research by Hendarwati et al. (2022, pp. 97-106) presented a "Cooperative Problem-Based Learning Model" by designing learning steps consisting of problem setting, management, group work to solve problems, work presentation, and evaluation. The results of the study confirm that it is an effective approach in producing graduates with skills ready for use in a highly competitive era.

From the literature review, it was found that although there is a large amount of research studying approaches to developing innovative thinking skills in various groups of students and vocational students. However, there is still no research that focuses on using problem-based learning management processes to develop innovative thinking skills in public administration students. Although personnel in this field play an important role in improving the efficiency of public services in the digital age, this study therefore aims to address the academic gap. It is hypothesized that "PBL learning management on the topic of “Designing Public Services and New Public Sector Operations Using Digital Technology” will result in a statistically significant increase in learning achievement and innovative thinking skills of public administration students."

III. RESEARCH METHODOLOGY

The research on the effects of problem-based learning management to develop innovative thinking skills, the researcher defined the independent variables as problem-based learning , consisting of (1) problem definition, (2) problem understanding, (3) knowledge formation, (4) knowledge synthesis, (5) summarizing and evaluating the answer, and (6) presenting and evaluating, and dependent variables are innovative thinking skills (Australian National Training Authority, 2001, p. 16-50). (1) Interpret, (2) Generate, (3) Collaborate, (4) Reflect, (5) Represent, and (6) Evaluate as detailed in Figure 1.

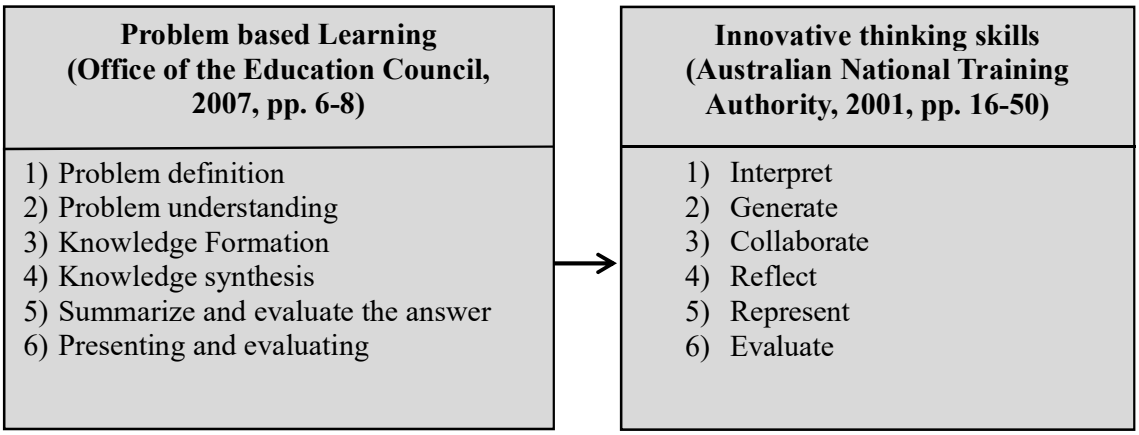

Figure 1: Conceptual framework

This research uses a one-group pretest-posttest design.

Population

The population comprised all third-year Public Administration students at the Faculty of Liberal Arts and Management, Prince of Songkla University, Surat Thani Campus, enrolled in the *Digital Civil Servant Competency Development* course in the first semester of the 2024 academic year. Using purposive sampling with a total population approach, 177 students were included. Eligibility required enrollment in the specified program and course with consent to participate, while students who failed to attend the full learning hours or complete key assessments were excluded. According to Krejcie and Morgan's (1970) sample size table, a population of 180 requires approximately 120–130 participants; thus, the inclusion of 177 students exceeded this threshold, ensuring both statistical power and comprehensive coverage of the accessible population.

Research instruments and quality inspection of instruments

1) A problem-based learning management plan on the topic of designing public services and new public sector operations using digital technology, totalling 26 hours. The content includes modern digital government transformation, government digital service, and important technology trends for digital government. Case studies of success in foreign countries and the service design thinking process. The concepts and principles of using problem-based learning (Office of the Education Council, 2007, p. 6) are used, consisting of 6 steps: (1) Problem definition (2) Problem understanding (3) Knowledge formation (4) Knowledge synthesis (5) Summarize and evaluate the answer and (6) Presenting and evaluating. The learning management plan was presented to 3 experts, consisting of 1 expert in the content of providing services and new public sector operations using digital technology, 1 expert in teaching, and 1 expert in measurement and evaluation. The appropriateness of the learning management plan was evaluated using a 5-level rating scale, with the average score of the learning management plan being 4.23, or at a high level.

2) A learning achievement test on the topic of designing public services and new public sector operations using digital technology. There are 4 essay questions, 5 points each, measuring learning achievement in terms of knowledge, understanding, application, and analysis. The quality of the instrument was checked by analyzing the validity of the test, presenting it to 3 experts, and then calculating the index of consistency between the objectives and the test. The validity of the entire test was 0.82. Then, the item difficulty index and the average difficulty of the test were analyzed. The learning achievement test was used with 44 students who were not in the sample group, who were 3rd-year public administration students who had studied the topic of designing public services and new public sector operations using digital technology. Then, the test results of each student were checked and scored. The test scores were arranged from highest to lowest. The test takers were divided into 3 groups: high scorers, low scorers, and medium scorers. The item difficulty index of the test was calculated, which was equal to 0.68. Then, the item discrimination index and the average discrimination of the test were analyzed using the formula by Scannell and Tracy (1975, p. 223). All test items had an IDisc > 0.30, and then the test was used as a research instrument with the sample group.

3) Innovative thinking skills assessment. The researcher developed it from the Australian National Training Authority (2001, pp. 16-50), consisting of 6 aspects: (1) context interpretation (2) idea creation (Generate) (3) collaboration with others (Collaborate) (4) idea reflection (Reflect) (5) idea presentation (Represent) and (6) success evaluation (Evaluate). The assessment form is a 5-level rating scale, and the innovative thinking skills assessment form was presented to 3 experts to check the content validity and calculate the item objective congruence index (IOC). The IOC value was 0.85.

4) Digital public service design assessment form (Rubrics). It was developed to be used as an instrument to assess students' ability to apply innovative concepts and digital technology in public service design. Important elements of service design in the public sector were assessed, including creativity and innovation, appropriateness to the context of government agencies, user-centric focus, appropriate use of digital technology, and ability to present work. The assessment criteria are divided into 4 levels: excellent (90-100 points), good (70-89 points), fair (50-69 points), and poor (0-49 points). In terms of checking the quality of research instruments, the researcher checked the content validity by presenting the assessment form to 3 experts to assess the consistency between the objectives and the assessment items. The assessment results showed that the IOC values were in the range of 0.67 - 1.00, which is within the acceptable. Furthermore, the instrument has also been checked for its feasibility in the actual teaching and learning context. The evaluators were able to spend appropriate time scoring each piece of work and analyzing the results in each aspect.

Data collection

1) Pre-experiment phase Before proceeding, details of the research were explained, including the objectives, operating procedures, and data collection methods. Students who were willing to participate in the research were asked to sign their names to consent to participate in the research. Then, students took a learning achievement test and an innovative thinking skills assessment before learning management.

2) Experiment phase Learning management was carried out according to the designed plan. Using the research instruments that were prepared in advance. Teaching was carried out by the researcher, which had problem-based learning management steps. Details in Table 1.

Table 1: Learning management steps on the topic of designing public services and new public sector operations using digital technology using problem-based learning

Steps	Activities
1) Problem definition (3 hours)	1) The instructor lectures on the topic of modern digital government transformation, Government Digital Service, and key technology trends for digital government (2 hours). 2) Students receive case studies of current public services and related problems, such as service delays, lack of convenience in accessing information, and the use of outdated technology. They then engage in a discussion to identify the main question requiring an answer: "How can we improve the efficiency of public service delivery using digital technology?" (1 hour).
2) Problem understanding (3 hours)	1) The instructor lectures on case studies of successful digital governments in foreign countries (Estonia and Singapore) (1 hour). 2) Students study case examples of successful digital governments and analyze their advantages and disadvantages. They then synthesize information from the case studies to understand the nature of the problems and the challenges in transforming government operations. Students are divided into groups of 5 to discuss and summarize approaches for implementation in Thailand. (2 hours)
3) Knowledge Formation (7 hours)	1)Each group of students conducts research on appropriate technologies to use in developing and improving digital public services. 2) Students interview individuals with experience in the public sector or experts to gather additional information (5 people). 3) Students survey the needs of citizens regarding access to digital public services (30 people).
4) Knowledge synthesis (3 hours)	1)The instructor lectures on the service design process (1 hour). 2) Students synthesize the information obtained from their research and analyze the feasibility of developing digital public services (1 hour). 3) Students brainstorm to find approaches for developing and designing services that meet the needs of public service users and create personas (user representatives) and user journeys to understand user behavior and test ideas (1 hour).
5) Summarize and evaluate the answer (3 hours)	1) Students summarize the results from the design process and present approaches for improving digital public services (1 hour). 2) Students discuss the advantages and limitations of their group's service design (1 hour). 3) Students review approaches that can be realistically applied to improve public services (1 hour).

Table 1: (Continued) Learning management steps on the topic of designing public services and new public sector operations using digital technology using problem-based learning

Steps	Activities
6) Presenting and evaluating (7 hours)	1) Each group of students presents their developed digital public service design, 10 minutes per group, followed by a 5-minute question and answer session. 2)The committee and instructors evaluate the designs in terms of appropriateness, feasibility, and potential impact. 3) Students revise and develop their approaches based on the feedback from the committee and instructors, and the revisions are reviewed.

3) Post-Experimental Phase: After the instructional activities, students completed a learning achievement test and an innovative thinking skills assessment. These instruments were used to evaluate the outcomes of the experimental learning intervention.

Data analysis

1) Learning Achievement: The pre-test and post-test scores were analyzed using the mean and standard deviation. A paired sample t-test was employed to compare the differences in learning achievement before and after the instructional intervention to determine the effectiveness of the learning activities.

2) Innovative Thinking Skills: The innovative thinking skills assessment was conducted before and after the learning activities. The analysis included the calculation of the mean, standard deviation, mean difference, and effect size. A paired sample t-test was used to examine whether there was a statistically significant improvement in students' innovative thinking skills after the implementation of problem-based learning (PBL). The effect size was interpreted to determine the magnitude of the instructional impact.

IV. RESULTS

The research findings are presented in accordance with the research objectives as follows:

1) Comparison of pre-test and post-test Scores

The results of the pre-test and post-test scores of 177 public administration students are in Table 2.

Table 2: Results of the Comparison between pre-test and post-test scores

Test	$\bar{x}$	SD	Mean difference	t	p-value
Pre-test	10.25	3.05	7.35	27.16	.00*
Post-test	17.60	3.65			

*p<.05

As shown in Table 2, the mean score before the learning intervention was 10.25 (SD = 3.05), while the mean score after the intervention was 17.60 (SD = 3.65). The mean difference between the pre-test and post-test scores was 7.35, with a t-value of 27.16 and a P-value of 0.00, indicating a statistically significant difference at the 0.05 level.

These findings suggest that the problem-based learning (PBL) approach used in the instructional plan on "Designing Digital Public Services and Government Operations" effectively enhanced students' learning achievement.

2) Comparison of innovative thinking skills before and after the learning activity

The results of innovative thinking skills before and after the learning activity are in Table 3.

Table 3: Comparison of innovative thinking skills before and after the learning activity

Innovative thinking skills	Paired differences					t	Sig (2 tailed)
	$\bar{x}$	SD	SD error mean	Lower	Upper		
1. Interpret	2.40	1.09	0.08	2.94	3.26	29.29	0.00**
2. Generate	2.10	1.10	0.09	3.07	3.43	25.40	0.00**
3. Collaborate	2.65	0.95	0.07	3.26	3.54	37.11	0.00**
4. Reflect	2.20	1.00	0.08	3.04	3.36	29.27	0.00**
5. Represent	2.15	1.05	0.08	2.99	3.31	27.24	0.00**
6. Evaluate	2.34	1.05	0.08	2.94	3.26	29.65	0.00**

*p<.05

As shown in Table 3, the results of the paired sample t-test comparing pre- and post-intervention scores across six dimensions of innovative thinking skills (1) Interpret, (2) Generate, (3) Collaborate, (4) Reflect, (5) Represent, and (6) Evaluate-demonstrated significant improvements in all areas. The mean differences for each dimension ranged from 2.10 to 2.65, indicating consistent and comprehensive progress among participants. The t-values were notably high, ranging from 25.40 to 37.11, with 2-tailed significance levels (Sig.) of 0.00 across all dimensions, clearly below the conventional significance threshold of $p < .05$.

These findings confirm that there were statistically significant differences in innovative thinking skills before and after the intervention, across all dimensions. This indicates that the learning activities implemented in this study were highly effective in fostering students' innovative thinking abilities in a multidimensional and holistic manner.

3) Results of the assessment of public service design projects in the digital era (Rubrics)

A total of 177 students were divided into groups to participate in collaborative learning activities. The grouping resulted in 35 teams, with most groups consisting of five members (35 groups × 5 students = 175 students), and the remaining two students were assigned to two groups of six members each, ensuring full participation of all students. Throughout the learning process, students collaboratively designed public service delivery models tailored to the digital era. The final presentations were evaluated using a rubric-based assessment with a maximum score of 100 points. The assessment results are presented in Table 4.

Table 4: Results of the evaluation of public service design projects in the digital era

Scoring levels for public service design project evaluation (Total Score: 100 points)		Number of groups	Percentage (%)
1)	Excellent**:** 90–100 points	12	34.29
2)	Good: 70–89 points	15	42.86
3)	Fair: 50–69 points	6	17.14
4)	Poor: 0–49 points	2	5.71
Total		**35**	**100**

As shown in Table 3, the evaluation results were categorized into four performance levels: Excellent (90–100 points), Good (70–89 points), Fair (50–69 points), and Poor (below 50 points). The results revealed that most student groups performed at a satisfactory level. Specifically, 12 groups (34.29%) achieved scores in the excellent range, followed by 15 groups (42.86%) in the good range. Together, these two categories accounted for 77.15% of all groups, indicating a strong understanding and skill in designing public service solutions that are potentially applicable in real-world contexts. Meanwhile, 6 groups (17.14%) fell into the fair category, and only 2 groups (5.71%) were assessed as poor. Although these latter groups represent a minority, the evaluation outcomes provide valuable feedback that can be used to inform and enhance future learning activities.

V. CONCLUSION AND DISCUSSION

The research aimed to evaluate the effectiveness of a Problem-Based Learning (PBL) approach on public administration students' learning achievement and innovative thinking skills, and to assess their public service design projects. The findings consistently demonstrate the positive impact of this intervention. Firstly, a comparison of pre- and post-intervention scores for public administration students revealed a statistically significant improvement in learning achievement, indicating that the PBL approach effectively enhanced students' learning outcomes. Secondly, the study found statistically significant improvements across all dimensions of innovative thinking skills - Interpret, Generate, Collaborate, Reflect, Represent, and Evaluate - after the learning activity, which confirms the effectiveness of the implemented learning activities in fostering students' innovative thinking abilities in a multidimensional and holistic manner. Finally, the assessment of public service design projects, undertaken by numerous student groups, demonstrated a high level of performance, with a substantial majority of groups achieving scores indicating good to excellent understanding and practical application of skills in designing public service solutions relevant to the digital era; only a minority of groups scored lower, providing valuable insights for future instructional refinement. In summary, the problem-based learning intervention significantly improved public administration students' learning achievement and innovative thinking skills across all measured dimensions and resulted in high-quality public service design projects. The learning intervention yielded statistically significant improvement in learning outcomes at the 0.05 level, affirming the effectiveness of the problem-based approach. These findings are consistent with Chachiyo and Chachiyo (2024, pp. 97-106), who demonstrated that PBL effectively enhances critical thinking skills among university students. Similarly, Chaimanee and Nuchprayoon (2024, pp. 54 - 65) reported that undergraduate students enrolled in a programming course exhibited significantly higher post-test scores following PBL instruction. The present study also revealed statistically significant improvements ($p < .05$) in six dimensions of innovative thinking: (1) Interpret, (2) Generate, (3) Collaborate, (4) Reflect, (5) Represent, and (6) Evaluate. This aligns with findings by Yawai et al. (2024, pp. 188-202), who integrated PBL with authentic work experiences to enhance teacher trainees' innovative thinking. Their research showed significant gains in post-intervention scores compared to pre- and mid-intervention levels. Similarly, Kardoyo et al. (2020, pp. 1141-1150) demonstrated that PBL strategies positively influence both analytical and

creative thinking among economics students at Universitas Negeri Semarang, Indonesia. Students were able to interpret cases accurately, propose feasible solutions, and express that PBL made learning more engaging and participatory. Furthermore, Ainthaphuk et al. (2025, p. LEADRU0201e1233) found that teachers in the Sukhothai Primary Educational Service Area 1 developed high levels of innovative thinking following targeted interventions. Liangaumnuay et al. (2024, pp. 11-21) emphasized that innovative thinking is essential to driving educational reform in Thailand's digital era, especially in science education, which requires adaptability and systemic problem-solving. Their proposed five-stage innovation process—problem identification, data collection, idea generation, development and testing, and implementation—can be effectively cultivated through experiential and problem-based learning. Such approaches foster key innovator traits, including initiative, leadership, integrative thinking, curiosity, and collaboration. In addition to aligning with prior studies, the findings can be interpreted through the lens of constructivist learning theory, which posits that learners actively construct knowledge through problem-solving and collaboration. The statistically significant improvements observed across all six dimensions of innovative thinking are consistent with this theoretical perspective, as PBL requires students to integrate prior knowledge, engage in reflective inquiry, and generate creative solutions in authentic contexts. An alternative explanation for these results may lie in the role of peer collaboration and group dynamics, which can stimulate idea generation and critical reflection beyond the effects of the PBL structure itself. Moreover, students' pre-existing familiarity with digital technologies may have amplified their ability to design innovative public service projects, suggesting that digital literacy acted as a moderating factor. These considerations highlight that while PBL was central to the observed improvements, other contextual and learner-related factors likely contributed, underscoring the importance of integrating multiple perspectives when interpreting the findings.

In summary, this research generates new knowledge in three important dimensions. First, it confirms the pedagogical effectiveness of Problem-Based Learning (PBL) in enhancing both learning achievement and innovative thinking skills of students in the field of public administration. Second, the findings contribute to the theoretical development of innovative thinking by providing a multidimensional framework (Interpret, Generate, Collaborate, Reflect, Represent, and Evaluate) that can serve as a reference for designing curricula in higher education. Third, this study expands the academic value of PBL by demonstrating its applicability to digital public service design, thereby offering new insights into how higher education can prepare students to become innovative citizens capable of addressing contemporary challenges in public sector contexts.

SUGGESTION

Based on the findings of this study, it is recommended that the problem-based learning (PBL) approach be systematically integrated into other courses within the Public Administration curriculum and related disciplines, particularly those emphasizing analytical thinking, systems thinking, and policy decision-making - such as Public Policy, Strategic Planning, and Public Sector Technology Management - to enhance students' comprehensive competencies. Learning activities should emphasize active student participation throughout the entire learning process,

including question formulation, data exploration, synthesis of innovative alternatives, and presentation of policy recommendations to relevant agencies, thereby fostering communication, teamwork, and leadership skills. Assessment results of students' skills and digital public service design outputs should be utilized as constructive feedback for ongoing instructional improvement, with targeted support mechanisms - such as focused workshops or structured mentoring -for students needing further development. Moreover, learning outcomes should be connected to real-world practices by encouraging universities to collaborate with local government units, enabling students to translate their classroom innovations into practical policy or service applications, thus contributing to tangible social impact and enhancing students' applied public administration competencies.

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DEVELOPMENT OF TEACHING MODEL BASED ON STEAM EDUCATION CONCEPT COMBINED WITH INTEGRATED TEACHING TO PROMOTE CREATIVE THINKING SKILLS FOR INNOVATIVE INTEGRATED AGRICULTURAL TECHNOLOGY

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Khrueahong, J., Poungsuk, P., & Junlek, P. (2025). Development of teaching model based on steam education concept combined with integrated teaching to promote creative thinking skills for innovative integrated agricultural technology**. International Journal of Industrial Education and Technology, 7** (2), 27 - 37.

ABSTRACT

This study was to develop teaching model based on STEAM education combined with integrated teaching, investigate an effect of using the teaching model based on the concept of STEAM education combined with the integrated teaching, and promote creative thinking skills for innovative integrated agricultural technology of Nakhon Sawan Rajabhat University students. The sample group consisted of 21 students who registered for the course Sustainable Agriculture and Smart Consumption in the first semester of the academic year 2024. They were obtained by simple random sampling (drawing). A single-group pre-test/post-test design was employed. This research and's development comprised six steps: 1) identifying the problem, 2) exploring related concepts, 3) designing a solution method, 4) developing, 5) presenting, and 6) evaluating. Data were analyzed using descriptive statistics and a paired-samples t-test to compare pre-test and post-test knowledge scores. Findings showed that the students had a higher level of knowledge than before with a statistical significance level at .001. It was found that the students had a highest level of skills in creative thinking ($\bar{x}$ = 3.37, SD = 0.58 on a 4-point scale) and they had a high level of satisfaction with the teaching model ($\bar{x}$ = 4.30, SD = 0.46 on a 5-point scale). This implied that the teaching model could be used for developing knowledge and skills in creative thinking for innovative integrated agricultural technology of Nakhon Sawan Rajabhat University students. Limitations include the small sample size, which may limit the generalizability of the findings.

Keywords: STEAM education, Creative thinking, Integrated teaching, Agricultural technology

I. INTRODUCTION

There was the announcement of the Ministry of Higher Education, Science, Research and Innovation on the desired skills of the workforce in the field of modern agriculture, 2002. In other words, it was the desired skills of modern agriculture entrepreneurs using technology and management for modern agricultural business operations and sustainability based on production problem solving by using innovation and technology (Announcement of the Ministry of Higher Education, Science, Research and Innovation on the Desired Skills of Workforce in Modern Agriculture, Digital Marketing, and New Forms of Tourism B.E. 2565, 2024: pp. 16-24). Hence, curriculum design and teaching/learning facilitation must be up-to-date. In fact, it is essential that effective citizen preparation in the 21st century be practiced. This is because the social changes that have occurred have had profound effects on the way of life of society. Importantly, the most important skill is learning skill that leads to establishing a conceptual framework and key strategies for managing learning in interdisciplinary content or topics for the 21st century. This can be done by promoting understanding of subject matter and integrating skills into all subjects, e.g. skills in learning and innovation, information technology, life and occupation, thinking, etc. (Tuntirojanawong, 2017, p. 2845).

The concept of STEAM education is a guideline for teaching/learning facilitation which five fields of study are integrated: Science, Technology, Engineering, Arts and Mathematics. It aims to develop analytical thinking, problem solving and all-round creativity of learners. As a matter of fact, STEAM education focuses on the learner to practice in the actual situation or through diverse activities such as creating experimental works and project design. This truly helps the learner be able to connect knowledge from many disciplines that can be used effectively in the real life. Besides, it promotes good attitude towards learning; particularly on science and technology as an important foundation for the country development in the 21st century (Choeichaeng, et al., 2022, pp. 70-78).

Furthermore, there is a report on use of STEAM education to develop creative thinking of secondary school students (Chanthong, 2019, p. 15; Chanintarapum, 2020, p.19; Hemkaew, 2025, p. 12) Education and local wisdom-based for education students. In this respect, the efficiency value was 8.00/86.92 higher than the 75/75 criterion with a significant level. The capability in learning design and creative skill after learning way higher than before with a significant level. Meanwhile, a level of awareness of local wisdom values before and after learning was different with a statistical significance level ($p<0.01$) (Nakwijit, 2020, pp. 220-224)

In this research, the objectives of this study were to: 1) develop teaching model based on STEAM education combined with integrated teaching; 2) investigate an effect of using the teaching model based on the concept of STEAM education combined with the integrated teaching; 3) promote creative thinking skills for innovative integrated agricultural technology of Nakhon Sawan Rajabhat University students.

II. LITERATURE REVIEW

Educational facilitation in the 21st century is now facing structural change at a global level which focuses on the creation of "A human being with all-round abilities". This is to cope with a rapidly changing world in terms of technology, economy and society. One of the most widely accepted and driven approaches is STEAM education. It is the integration of five aspects: science, technology, engineering, arts and mathematics as an important foundation of skill development in the 21st century. It includes analytical thinking, problem solving, systematic thinking and learning by doing. It can be observed that the learner do not study subjects separately as in the old system, but rather practices integrating knowledge to solve problems or create works in real situations. This is through projects or activities focusing on creative thinking and engineering thinking. Later on, South Korea, one of the educational development leaders, puts the importance on the dimensions of culture, languages and arts. Thus, STEAM education is developed by adding arts leading to STEAM education. This emphasizes on the development of learners to have a balance of both reason and emotion. It also promotes imagination, creative thinking and effective communication which are the heart of innovation in the digital age (Jaradrawiwat, 2017, pp. 21-25).

Furthermore, development of the learner focuses on the study of learning development theory of Bloom. He devised learning objectives into three aspects: 1) Cognitive Domain, 2) Affective Domain, and 3) Psychomotor Domain. All of these are used for Pre-test/Post-test design to distinguish knowledge, thought and intelligence into different levels. In addition, it helps adjust content, searching for techniques and methods, and organizing teaching/learning activities that are appropriate for learners to promote their potential development as set (Bloom et al., 1956; Anderson et al., 2001, p. 67). Existing Bloom's Taxonomy is improved to be appropriate with learning in the 21st century. That is, there is a shift from knowledge-based learning to thinking-based learning (Cognitive processes). This consists of six levels: 1) remember, 2) understand, 3) apply, 4) analyze, 5) evaluate and 6) create. Particularly, the "create" level is emphasized as the highest point of learning. This is because it is a process which the learner can combine body of knowledge, skills and experience together in order to create concepts, methods or new meaningful or worthwhile works. Meanwhile, Amabile (1996, pp. 115-117) proposed theory of components of creativity divided into internal personal component (i.e. domain-relevant skills or expertise reflecting knowledge and skills related to creativity relevant processes or creativity skills). It covers intellectual methods, problem-solving, strategies and personal characteristics such as flexibility, tolerance, and risk taking. It includes task motivation which an internal driving source that directly influences creative efforts. Meanwhile, external personal components such as social environment which can promote or hinder the creative process of an individual. Thus, creative thinking does not occur from only one factor, but it is the sum of a complex system of elements. In fact, Amabile puts the importance on novelty and usefulness as important true indicators of creative works. In addition, creative thinking consists of two principles problem exploring and problem solving. Hence, creative thinking needs various skills and existing thinking must always be adjusted. Indeed, innovation is built on creativity, which is a fundamental element of corporate innovation. That is, creativity is used within an organization in order to be successful. In general, innovation is different from creativity because it focuses on the application in economic environment. Hence, the relationship between creativity and innovation can be

viewed from two perspectives: the first one seen creativity as the creation of ideas, while innovation as the application of ideas. The second one is the combination of both creativity and innovation together. This is, creativity is the initial step of innovation process. So, creativity is the idea component of innovation and innovation covers the application and new ideas or concepts (Peerapan et al., 2023, p. 309). Therefore, the researcher anticipates that first-year students who receive instruction through an integrated STEAM-based teaching model will exhibit increased creative thinking skills in innovative integrated agricultural technology.

III. RESEARCH METHODOLOGY

Conceptual Framework

According to the research, concepts and theory as mentioned, the researcher set a conceptual framework of this study. It comprised six steps of learning experience management:1) problem identifying, 2) exploring related concepts, 3) problem solving design method, 4) developing, 5) presenting, and 6) evaluating (Figure 1)

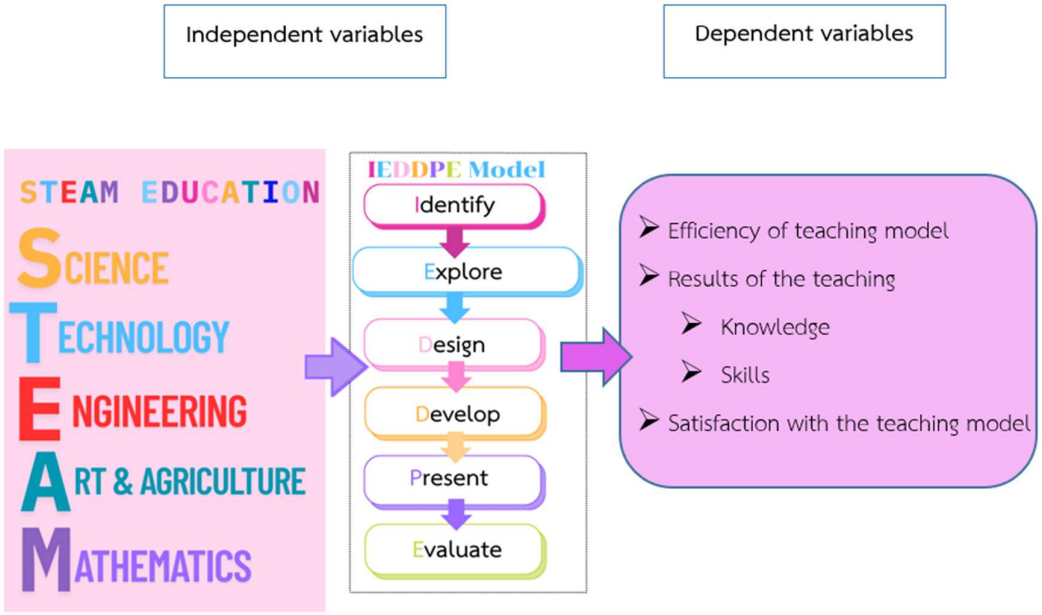

Figure 1: Conceptual framework

Based on the conceptual framework, three hypotheses were developed to achieve the research objectives: (1) the efficiency (E1/E2) of the developed teaching model integrating STEAM (Science, Technology, Engineering, Art & Agriculture, Mathematics) and the IEDDPE process would meet or exceed the predetermined criterion (80/80); (2) students' learning outcomes in terms of knowledge and skills after learning through the IEDDPE teaching model would be significantly higher than their outcomes before learning ($p < .05$); and (3) students would demonstrate a high level of satisfaction with the teaching model based on STEAM and the IEDDPE process. This study followed a Research and Development (R&D) framework, beginning with the systematic development and validation of the

integrated STEAM teaching model and its assessment instruments. A quasi-experimental one-group pretest-posttest design was then employed to evaluate the model's effectiveness by measuring significant changes in students' knowledge and creative thinking skills resulting from the intervention.

Population and Sample Groups

The population in this study were Nakhon Sawan Rajabhat university students who registered the course "Sustainable Agriculture and Smart Consumption" in the first semester of the academic year 2024 (7 sections or 151 students). The sample group consisted of one section or 21 students obtained by simple random sampling.

Research instruments

The research instruments included: (1) an integrated STEAM learning unit and learning management plan on integrated agricultural technology, (2) a knowledge test, (3) an evaluation form assessing creative skills for integrated agricultural technology and innovation, and (4) an evaluation form measuring students' satisfaction with the teaching model.

Quality control of research instruments

1. Development of integrated STEAM learning unit learning facilitation plan on the topic of integrated agricultural technology. It had the following steps to create:

1.1 Studied the characteristics of the learning management. Also, studied the General Education curriculum of Nakhon Sawan Rajabhat university (Course: Sustainable Agriculture and Smart Consumption). The topic was "Integrated Agricultural Technology: A Guideline for Creating the Learning Facilitation Plan".

1.2 Studied the content of integrated farming and the Learning theory of Bloom, Constructivist theory, concepts and theories related to innovative creativity from various documents as guidelines for creating the learning facilitation plan

1.3 These details were used to determine the learning facilitation plan on integrated farming as shown in Table 1.

Table 1: Integrated. Agricultural Technology curriculum schedule

Integration					Situation	Work piece	Hours
Science	Technology	Engineering	Art and Agriculture	Mathematics			
Knowledge about soil, minerals, air and water for cultivation and animal domesticati on	Application of integrated farming technology	The process of creating simulated mixed farming calculation of construction costs	Integrated farming design	Computation of an area for planning integrated farming	Students were assigned to design an integrated farm of their own with unlimited capital and space	Integrated farming farm design	9

1.4. The learning facilitation plan was checked by five specialists and the IOC was found at 0.60-1.00 Then, it was improved based on suggestions of the specialists (Language used, content and time span).

1.5 The learning facilitation plan was tried out with students who not included in the sample group. After improvement, it was used with the sample group.

2. Knowledge test

The following were construction steps:

2.1 Studied documents related to measurement evaluation of the construction of integrated farming. Then, analysed objective and content based on the teaching/learning facilitation plan.

2.2 Constructed the knowledge test analysis table based on six aspects of behaviour: memory, understanding, application, analysis, assessment and creativity. After that, the knowledge test was checked by the five specialists on the basis of use of questions, questions format, options, consistency with the behaviour to be measured, linguistics accuracy and content validity. Also, the consistency between the questions and the behavioural characteristics of 30 items was considered (Item Objective Congruence Index-IOC)

2.3 Obtained scores were used to calculate the index of consistency between the questions and the behaviour, selecting only the items with an index value of 0.05 and above to represent the behaviour group with content validity. However, item with values less than 0.05 were removed or adjusted for suitability before use.

2.4 The improved knowledge test was tried out with the students who were not included in the sample group. The scores were scored on a scale of one for the correct answer and zero for the incorrect answer. After that, an analysis of difficulty and discrimination values was conducted. Items with difficulty values between 0.20-0.80 and discrimination values at 0.20 and above were selected to gain 20 questions that were based on the analysis table.

2.5 The selected knowledge test was tried out with the students who were not included in the sample group to find the reliability by using KR-20 formula, found at 0.71. After that, the selected knowledge test was used with the sample group.

3. Assessment form of creative thinking skills in integrated agricultural technology innovation

3.1 Measurement form on creative thinking skills to be used as a tool for data collection related to creative thinking skills of the students after organizing integrated STEAM learning activities. It had the following steps for construction:

3.1.1 The researcher studied academic documents and research related to creative thinking in integrated agricultural technology innovation. This aimed to determine the framework for studying the components of student characteristics having creative and innovative skills.

3.1.2 The researcher constructed innovative creative thinking skills model based on integrated learning activities of STEAM education

3.1.3 The model was checked by five specialists and then improved based on their suggestions (Language used). After that it was tried out with the sample group.

4. A form measuring the student satisfaction

It had the following construction steps:

4.1 Studied related documents, textbooks and research to prepare the form measuring the student satisfaction with the teaching model.

4.2 Constructed the 5-rating scale questionnaire by specifying the questions regarding content, activities and training media, and assessment

4.3 The student satisfaction assessment form was checked by the five specialists based on validity and IOC regarded as an acceptable quality learning facilitation plan having an index value of 0.5 and above

4.4 The student satisfaction assessment form was checked for finding the reliability value (0.74) using α-Coefficient of Cronbach (1990)

Conducting the research and analysing research data

1. The researcher collected data by herself as follows:

1.1 The sample group took the pre-test prepared by the researcher.

1.2 The researcher conducted the teaching/learning facilitation by herself for three weeks, three hours each. It was the integrated learning to promote creative thinking in technological. This comprised six steps: 1) problem identifying, 2) exploring related concepts, 3) problem solving method designing, 4) developing, 5) presenting, and 6) evaluating. After finishing the three weeks of teaching/learning facilitation, the sample took the post-test prepared by the researcher.

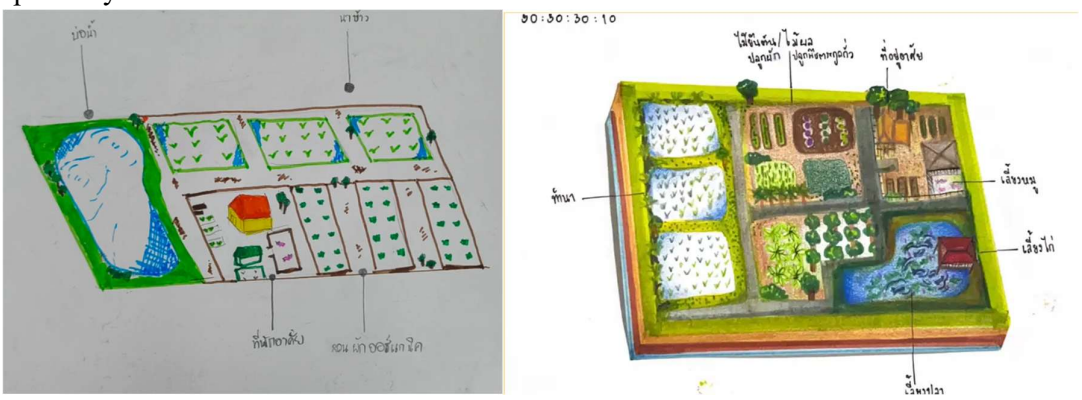

Figure 2: Teaching and learning activities during the design and development stage

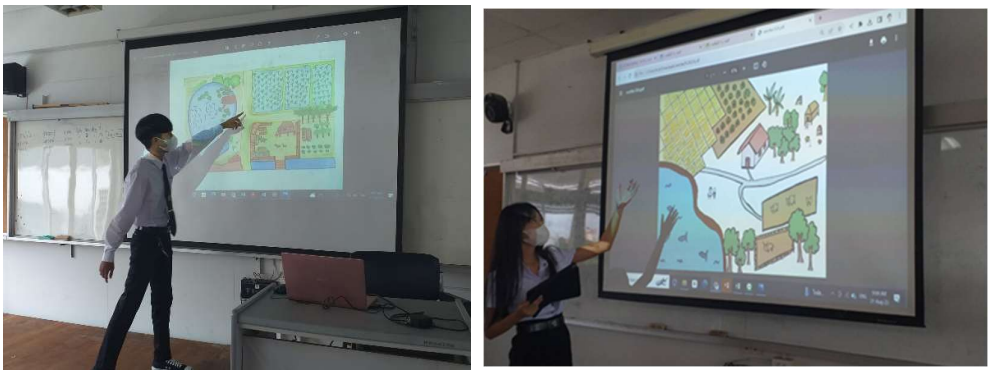

Figure 3: Instructional activities in the presentation step

2. Data analyses

The researcher analyzed various data by using the statistical package as follows:

2.1 Basic statistics - mean and standard deviation

2.2 Hypothesis testing statistics comparing academic achievement results before and after studying of the sample group by using Dependent Samples t-test.

IV. RESULTS

Results of the integrated teaching/learning facilitation to promote skills in creative thinking in innovation in integrated agricultural technology of the sample group (Nakhon Sawan Rajabhat university students) based on IEDDPE model (According to E1/E2 criteria, the first assumption was satisfied). It was found that the efficiency of the teaching model based on the concept of STEAM education combined with integrated teaching met the criteria of 80.48/87.38. Findings showed that the post-test scores were higher than the pre-test scores with a statistical significance level at .05. In other words, an average pre-test score was 9.70 (SD = 1.60) whereas that of the post-test was 15.03 (SD = 1.59) as shown in Table 2.

Table 2: Results of the comparison of scores of knowledge the pre-test and post-test

Knowledge	n	Total score	$\bar{x}$	SD	t	Sig
Before learning	21	20	9.70	1.60	15.84*	.000
After learning	21	20	15.03	1.59		

Table 3: Results of an assessment of skills in creative thinking in integrated agricultural technology innovation

Item	$\bar{x}$	SD	Description
1.Innovative creativity	3.48	0.68	Highest
2.Accuracy in work and completion of work on time	3.10	0.30	High
3.Ability to apply STEAM education knowledge	3.52	0.51	Highest
Total	**3.37**	**0.58**	**Highest**

Legend: 3.26-4.00, Highest, 2.51-3.25 High, 1.76-2.50 Low, 1.00-1.75 Lowest.

According to Table 3 as a whole, it was found that the sample group had a highest level of skills in creative thinking in integrated agricultural technology innovation ($\bar{x}$ = 3.37, SD = 0.58). Based on its detail, innovative creativity and ability to apply STEAM education knowledge were found at a highest level whereas accuracy in work and completion of work on time was found at a high level.

Table 4: Student satisfaction with the teaching model in accordance with STEAM education and integrated learning

Item	$\bar{x}$	SD	Description
Teaching/learning facilitation			
1. Students review prior knowledge and connect it to new content knowledge.	4.05	0.22	High
2. Students exchange knowledge with the lecturer and their classmates.	4.48	0.51	High
3. Students have an opportunity to ask questions when they do not understand.	4.38	0.50	High
4. Students participate in discussions and connect new knowledge to conclusions.	4.38	0.50	High
5. Students practice knowledge create innovations and present their work.	4.29	0.46	High
Total	**4.31**	**0.47**	**High**

Table 4: (Continued) Student satisfaction with the teaching model in accordance with STEAM education and integrated learning

Item	$\bar{x}$	SD	Description
Innovation in agricultural technology			
1. Students have thought process which is systematically linked and interrelated.	4.05	0.22	High
2. Students have a progressive nature.	4.24	0.44	High
3. Students transfer their ideas through speaking, writing and drawing pictures.	4.29	0.46	High
4. Students use technology for changes by using various techniques.	4.33	0.48	High
5. Students have an opportunity to check their own work and improve it.	4.33	0.48	High
6. Students have an opportunity to work and share knowledge with others.	4.48	0.51	High
Total	**4.29**	**0.45**	**High**
As a whole	**4.30**	**0.46**	**High**

Legends: 4.50-5.00 Highest, 3.50-4.49 High, 2.50-3.49 Moderate. 1.50-2.49 Low, 1.00- 1.49 Lowest.

According to Table 4, it was found that as a whole, the sample group had a high-level satisfaction with the teaching model ($\bar{x}$ = 4,30, SD = 0.46). Based on the teaching/learning facilitation, they also had a high level of satisfaction ($\bar{x}$ = 4.31, SD = 0.47). For its details, they had a high level of an opportunity to exchange knowledge with the lecturer and their classmates most ($\bar{x}$ =4.48, SD 0.51). On the basis of innovation in agricultural technology, as a whole, the sample group had a high level of it ($\bar{x}$ = 4.29, SD = 0.51). Based on its the details, they had a high level of thought process which is systematically linked and interrelated least ($\bar{x}$ = 4.05, SD = 0.22). However, they had a high level of an opportunity to work and share knowledge with other most ($\bar{x}$ = 4.48, SD = 0.51).

V. CONCLUSION AND DISCUSSION

In conclusion, the core findings of this research demonstrate that the IEDDPE teaching model, as a structured application of STEAM principles, was efficient and effective. The model successfully promoted knowledge of integrated agriculture, verifiably enhanced creative thinking skills for agricultural innovations (with students achieving a high-level mean score of 3.37), and was well-received by students, as evidenced by a high level of satisfaction ($\bar{x}$ = 4.31). This study confirms that an integrated, project-based approach can effectively develop the specific 21st-century skills required in modern agricultural technology education. However, this study's limitations primarily involve generalizability, given the small sample size (n=21) sourced from a single university via cluster sampling, and internal validity, due to the one-group pretest-posttest design which lacks a control group. The brief 9-hour intervention also makes the long-term durability of the acquired skills uncertain. Therefore, future research should replicate this study using a more robust quasi-experimental design with a control group to confirm the IEDDPE model's effectiveness. We also recommend expanding the research to

include larger, more diverse samples from multiple institutions to enhance generalizability, conducting a longitudinal study to assess the long-term retention of creative thinking skills, and broadening the assessment to include other 21st-century variables such as collaboration and critical thinking.

The integration of STEAM education (Science, Technology, Engineering, Arts and Agriculture, Mathematics) within the IEDDPE teaching model significantly enhanced students' understanding of subject content and their ability to synthesize knowledge across disciplines to create agricultural technology innovations, aligning with Yakman (2008, p. 1) assertion that STEAM education promotes creative and integrated learning by enabling learners to perceive relationships among knowledge domains and apply them to problem-solving. The six-step IEDDPE framework-problem identifying, exploring related concepts, problem solving method design, planning and developing, solution presenting, and evaluating-corresponds closely with Riley's (2012) guidelines for STEAM-based instruction, which emphasizes creative thinking through systematic problem-solving processes. The model's effectiveness was demonstrated through high student satisfaction ($\bar{x}$ = 4.31, SD = 0.47), reflecting its success in promoting experiential learning, analytical thinking, and interdisciplinary knowledge integration while fostering essential 21st-century skills such as teamwork and effective communication. Most notably, students achieved the highest level of creative thinking in agricultural technology innovations ($\bar{x}$ = 3.37, SD = 0.58), supporting Guilford's (1967) and Torrance's (1974) theories that creative thinking can be developed through appropriate pedagogical approaches. These findings are consistent with recent studies demonstrating the efficacy of integrated STEAM approaches: for instance, Jaradrawiwat (2017, p. 19) noted that Thailand's integrated learning through STEM, STEAM, and STREAM concepts develops analytical thinking and real-world knowledge application aligned with current educational policies; similarly, Chanintarapum (2020 p. 19) found that learners demonstrated significantly higher technological innovation skills after STEAM-based instruction ($p < .05$); and Malikhao et al. (2022, p. 79) reported that primary students' creative thinking improved by over 60% ($p < .05$) following STEAM education integrated with sufficiency economy principles, with self-sufficiency characteristics reaching excellence levels ($\bar{x} = 2.70$), thereby validating the efficacy of interdisciplinary approaches in developing higher-order thinking skills and preparing learners for contemporary educational demands.

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PRE-SEISMIC IONOSPHERIC TOTAL ELECTRON CONTENT ANOMALIES ASSOCIATED WITH THE JUNE 28, 2023, EARTHQUAKE IN THAILAND

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ABSTRACT

This study investigated ionospheric Total Electron Content (TEC) anomalies as potential precursors to a moderate earthquake magnitude of 4.5 that occurred in Phai Lom, Bang Krathum District, Phitsanulok Province, Northern Thailand, on June 28, 2023 (Universal Time, UT). High-resolution GPS data from the UTHG GNSS station were analyzed at 1-second intervals over 15 days (June 21–July 5, 2023) using the ±2σ statistical boundary method to detect abnormal variations in TEC. The analysis revealed a pronounced TEC enhancement of approximately 2.61 TECU on June 23, five days before the earthquake, followed by a significant depletion on the day of the event. These variations exceeded the Upper and Lower statistical limits (UB and LB), indicating statistically significant deviations from the expected median trend. A moderate geomagnetic storm (Dst = –57 nT) was recorded on June 25; however, correlation analysis (r = –0.507) indicated only a moderate negative relationship between geomagnetic activity and TEC variations. During the earthquake period, the Dst index remained above –30 nT, signifying geomagnetically quiet conditions. To validate the findings, global TEC data obtained from the GNSS-TEC database displayed consistent temporal trends, confirming that the anomalies were not site-specific. Moreover, analysis of the Rate of TEC Index (ROTI) revealed short-term irregularities on June 23 and June 28 UT, further supporting the presence of ionospheric disturbances related to the seismic event. Overall, these results align with previous studies and emphasize the potential of GNSS-based ionospheric monitoring and correlation

analysis as reliable tools for short-term earthquake forecasting, particularly in low-latitude regions such as Thailand.

Keywords: Total electron content, Earthquake, Global navigation satellite system, Rate of TEC Index, GPS

I. INTRODUCTION

Earthquakes are natural phenomena caused by the sudden release of energy due to movement within the Earth's crust. They can occur unpredictably at any time and place, with intensities ranging from imperceptible tremors to catastrophic events that inflict severe damage to lives and property. Although Thailand is not located directly on a major tectonic plate boundary, the Department of Meteorology, Thailand, has reported the existence of 16 active fault zones within the country (Thai Meteorological Department: TMD, 2017). Historical records indicate that Thailand frequently experiences ground-level seismic shaking induced by domestic fault movements and by large-scale earthquakes originating in neighboring countries, such as Myanmar, Laos, and Indonesia, as well as the Andaman Sea. One of the most catastrophic events was the undersea earthquake in the Andaman Sea on December 26, 2004, with a moment magnitude of 9.1–9.3, which triggered a massive tsunami. This disaster claimed the lives of over 5,000 individuals in Thailand and more than 200,000 globally (TMD, 2017; United States Geological Survey: USGS, 2004). On June 28, 2023 (17:17:56, UT), an earthquake with a magnitude of MLv 4.5 at a depth of 5 kilometers (km) occurred at the epicenter near Ban Phai Lom, Bang Krathum, Phitsanulok (TMD, 2023). The cause of this earthquake was attributed to the movement of a hidden fault beneath the surface. This observation aligns with data from the USGS, which revealed the presence of many fault lines beneath the sediment layers near the Phitsanulok Basin. Interestingly, this fault line is distinct from the 16 main active fault line groups and has released unprecedented seismic energy over the past 100 years. This event was the most intense earthquake recorded in Phitsanulok over the past nine years of seismic monitoring. Despite being a relatively shallow earthquake, its strong shaking was widely felt by the general population in provinces such as Phitsanulok, Phichit, Kamphaeng Phet, Phetchabun, Nakhon Sawan, and Loei (TMD, 2023).

Despite advances in seismology, the precise prediction of earthquakes in terms of time, location, and magnitude remains unresolved. In response, we explored alternative approaches for detecting pre-seismic signals. One promising avenue involves using data from the Global Navigation Satellite System (GNSS), specifically the analysis of Total Electron Content (TEC) in the ionosphere. Variations in TEC are believed to be influenced by crustal stress accumulation, which can alter geomagnetic fields (Hofmann-Wellenhof et al., 1992, pp. 1–382; Pi et al., 1997, pp. 2283–2286; Skone & de Jong, 2014, pp. 1067–1071; Chernyshov et al., 2020, pp. 1–13; Pansong et al., 2025, pp. 7521–7532) and charged particle dynamics before seismic events (Murai, as cited in Xu et al., 2022, pp. 1–24; Liu et al., 2004, pp. 1585–1593; Pulinets, 2004, pp. 413–436; Xia et al., 2011, pp. 177–185; Heki, 2011, pp. 1–5; Cahyadi and Heki, 2013, pp. 1777-1787; Shah and Jin, 2015, pp. 42–49; Grawe and Makela, 2015, pp. 472–483; Sharma et al., 2017, pp. 65-74; Ulukavak and Inyurt, 2020, pp. 123–130; Kiyani et al., 2020, pp. 1-8; Nishioka et al., 2021, pp. 1-12; Guo et al., 2022, pp. 1-17; Sharma

et al., 2022, pp. 1–11; Nayak et al., 2024, pp. 1–21; Semlali et al., 2025, pp. 7589–7609). TEC variability arises from a complex interplay of factors that can be broadly categorized into five categories. First, space weather conditions, including solar radiation (EUV, X-rays), solar wind, solar flares, and Coronal Mass Ejections (CMEs), have a substantial influence. These phenomena, along with geomagnetic indices (e.g., Kp, Dst, and AE) and ionospheric electric fields, such as the Prompt Penetration Electric Field (PPEF) and Equatorial Electrojet (EEJ), contribute to phenomena such as the Equatorial Ionization Anomaly (EIA). Second, geographical and temporal factors, including latitude, longitude, seasonal cycles, diurnal variations, and local time, affect the distribution of TEC. Third, atmospheric coupling processes, such as gravity waves and meteorological phenomena, such as typhoons, also play a role. Fourth, lithospheric sources, such as gas or electric charge release from fault zones or volcanic eruptions, can have a transient impact on ionospheric conditions. Finally, biases in satellite signals or GNSS receivers may introduce errors in TEC estimation, necessitating correction techniques to ensure data integrity.

Previous studies have established correlations between TEC anomalies and seismic events in various regions worldwide. For example, Liu et al. (2004, pp. 1585–1593) studied pre-earthquake ionospheric perturbations recorded using continuous GPS TEC measurements. Afraimovich et al. (2004, pp. 339–354) analyzed TEC variations during the Hector Mine earthquake in California. Nishioka et al. (2021, pp. 1–12) conducted a long-term statistical analysis of TEC values over 22 years (1997–2018) in Japan, estimating 100-year return period TEC values to be 150–190 TECU in Tokyo, 180–230 TECU in Kagoshima, and 120–150 TECU in Hokkaido. Several studies have demonstrated a relationship between TEC anomalies and large earthquakes. Heki (2011, pp. 1–5) observed post-seismic increases in ionospheric electron density, though in some cases, anomalies occurred before the event. Similarly, Cahyadi and Heki (2013, pp. 1777–1787) reported TEC anomalies before the 2007 Bengkulu and 2005 Nias earthquakes in Sumatra. Shah and Jin (2015, pp. 42–49) analyzed global seismic events ($Mw \geq 5.0$) from 1998 to 2014 and found significant increases in TEC five days before earthquakes of $Mw \geq 6.0$, with 95% confidence. Their results also indicated that shallow earthquakes (depth < 60 km) have a more pronounced effect on the TEC. Sharma et al. (2017, pp. 65–74) developed a TEC-based model to detect seismic precursors in the Himalayan region, accounting for confounding factors such as geomagnetic storms and solar flares. Further evidence was presented by Ulukavak and Inyurt (2020, pp. 123–130), who reported that even small earthquakes (Mw 2.0–2.5) could induce TEC anomalies due to acoustic-gravity waves, with effects observed for up to 30 days (15 days before and after the event). In Taiwan, Guo et al. (2022, pp. 1–17) observed TEC anomalies 13–20 days before major seismic events. Semlali et al. (2025, pp. 7589–7609) studied the global correlation between Swarm satellite data and M4+ earthquakes from 2014 to 2024. They found a positive anomaly in the Magnetic Field Vector Y-component (MFV-Y) and TEC that were identified one to seven days before the earthquakes analyzed. In Southeast Asia, Kumar and Singh (2017, pp. 795–801) analyzed GPS-derived TEC data from the CUSV station in Thailand and the HYDE station in India for the 2016 Tamenglong earthquake (Mw 6.7), revealing a 47% increase in TEC about three days before the event, independent of geomagnetic influences. Eshkuvatov et al. (2025) further examined GNSS-derived TEC data from the CMUM and CUSV stations in Thailand during the Mw 7.7 Myanmar earthquake and identified anomalies

3–13 days before the mainshock. In Thailand, Pansong and Kenpankho (2025, pp. 297–312) investigated 473 earthquakes (Mw ≥ 3.0) during Solar Cycle 24 using GPS-, IGS-, and IRI-based TEC data. They observed no significant TEC correlation for Mw < 5.0, but moderate negative correlations ($r \approx -0.5$) for larger events, with TEC increasing slightly before, dropping during, and returning to normal after earthquakes. Collectively, many studies confirm the TEC–earthquake coupling mechanism and highlight the potential of GNSS-based monitoring for regional precursor detection.

Although many studies have reported correlations between ionospheric TEC variations and seismic activity worldwide, research on this topic in Thailand and Southeast Asia remains limited. Given the region's complex tectonic structure and multiple active fault zones, this study utilizes GNSS-derived TEC data to analyze ionospheric variations preceding the Phitsanulok earthquake of June 28, 2023 (UT). The Rate of TEC Index (ROTI) method was applied to identify potential pre-earthquake anomalies and to assess their temporal and spatial characteristics. In addition, the relationship between TEC variations and geomagnetic storm conditions during the earthquake period was examined to minimize the influence of external factors in this analysis. The objective is to determine whether detectable TEC disturbances occurred before the event and to evaluate their potential as short-term earthquake precursors. The findings are expected to enhance understanding of lithosphere–ionosphere interactions and support the development of more effective earthquake early-warning systems in Thailand.

II. LITERATURE REVIEW

A growing body of research has demonstrated that ionospheric TEC irregularities may serve as short-term indicators of significant seismic events. Liu et al. (2004, pp. 1585–1593) identified that 80% of large earthquakes (Mw ≥ 6.0) in Taiwan between 1999 and 2002 were preceded by nighttime TEC anomalies, particularly within five days before the mainshock. Similarly, Pulinets (2004, pp. 413-436) developed theoretical models and statistical techniques to identify ionospheric signals that could be applied to earthquake forecasting and prediction. In another high-magnitude event, Xia et al. (2011, pp. 177–185) observed consistent TEC patterns in the Qinghai–Tibet region, including two enhancement phases (at 9 and 2–3 days prior) and a period of reduced TEC (3–6 days before the events), regardless of geomagnetic interference. Heki (2011, pp. 1–5) reported a positive TEC anomaly approximately 40 minutes before the 2011 Tohoku-Oki earthquake (Mw 9.0), a finding echoed in prior mega-earthquakes such as the 2010 Chile and 2004 Sumatra–Andaman events. Cahyadi and Heki (2013, pp. 1777–1787) also reported co- and pre-seismic TEC fluctuations for the 2007 Bengkulu and 2005 Nias earthquakes, although long-term precursors were not detected in every case. Shah and Jin (2015, pp. 42–49) conducted a global analysis of 1492 earthquakes (Mw ≥ 5.0) and revealed significant TEC enhancements five days in advance of shallow quakes (depth < 60 km) of Mw ≥ 6 with high statistical confidence. Grawe and Makela (2015, pp. 472–483) explored tsunami-induced ionospheric signatures from the 2010 Chile, 2011 Tohoku, and 2012 Haida Gwaii events, underlining the roles of tsunami propagation direction and line-of-sight geometry. Kumar and Singh (2017) investigated pre-seismic ionospheric anomalies associated with the 2016 Tamenglong earthquake (M 6.7) in Northeast India using GPS-derived TEC observations. TEC data were analyzed from the CUSV station in Thailand and the HYDE

station in India to examine variations before and after the earthquake. The study applied differential TEC analysis to identify ionospheric perturbations independent of geomagnetic effects and space weather influences. Results revealed significant TEC enhancements of up to 47% approximately three days before the main shock, which gradually returned to normal afterward. In the Himalayan region, Sharma et al. (2017, pp. 65–74) modeled TEC behavior using GNSS data. They emphasized the need to account for non-seismic drivers, such as solar flares and geomagnetic storms. Ulukavak and Inyurt (2020, pp. 123–130) noted that seismo-ionospheric perturbations can emerge up to 15 days before and persist for up to two weeks after earthquakes. In parallel, Kiyani et al. (2020, pp. 1–8) identified low-intensity TEC deviations up to 10 days before the 2018 Fiji earthquake (Mw 8.2), distinguishing them from the post-seismic geomagnetic anomalies. Nishioka et al. (2021, pp. 1–12) provided statistical thresholds for extreme TEC levels in Japan based on two decades of observations, supporting the interpretation of anomalous values within a broader historical context. Similarly, Guo et al. (2022, pp. 1–17) used satellite and Global Ionospheric Maps (GIM) data to detect TEC anomalies 13–20 days before earthquakes in Taiwan, even in magnetically quiet conditions, with pre-earthquake Ne enhancements noted in the days leading up to the event. In addition, Semlali et al. (2025, pp. 7589–7609) investigated the global correlation between Swarm satellite data and M4+ earthquakes from 2014 to 2024, focusing on anomalies in MFV-Y and TEC as potential seismic precursors. Using over 200,000 earthquake events and data from three Swarm satellites, they compared observed MFV-Y and TEC values with modeled expectations from the International Geomagnetic Reference Field (IGRF) and the International Reference Ionosphere (IRI) 2020 to identify anomalies using the Unbiased Root Mean Square Difference (UbRMSD). Filtering techniques were applied to mitigate solar and geomagnetic disturbances, and the data were spatially and temporally normalized. The study employed advanced statistical methods, including Confusion Matrices (CM) and Receiver Operating Characteristic (ROC) curves, to evaluate the reliability of these anomalies in predicting seismic events. The results showed that positive MFV-Y and TEC anomalies often occurred 1–7 days before earthquakes, with better detection performance for larger magnitude events (M7+). Although high alarm rates persisted owing to overlapping ionospheric noise and solar activity, the research suggests that optimized thresholds (5 nT for MFV-Y and 0.5 TECU for TEC) can enhance early warning capability. Ultimately, this study underscores the potential of combining Swarm satellite data with statistical modeling to improve short-term earthquake forecasting, while also calling for the integration of additional geophysical indicators to reduce uncertainty and increase prediction reliability. Eshkuvatov et al. (2025) analyzed GNSS-derived TEC data from the CMUM and CUSV stations in Thailand, which were located near the Mw 7.7 earthquake in Mandalay, Myanmar. Applying the LAIC model and using input parameters from the OMNIWeb database, they examined TEC variability over 31 days and detected anomalous TEC variations 3–13 days before the main shock. Their results support the viability of GNSS-TEC monitoring as a precursor indicator of seismic activity in the Southeast Asian region, thereby providing concrete evidence that TEC-earthquake coupling can be studied using Thai station data. Additionally, Pansong and Kenpankho (2025, pp. 297–312) investigated the relationship between TEC anomalies in the ionosphere and earthquake events in Thailand during Solar Cycle 24 (2007–2020).

The research aimed to identify possible ionospheric precursors associated with moderate-to-large earthquakes by analyzing variations in TEC obtained from three sources: GPS TEC derived from 15 GNSS stations across Thailand, IGS TEC from the GIM, and IRI TEC from the International Reference Ionosphere model. A total of 473 earthquake events with magnitudes of 3.0 Mw or greater were analyzed, based on data from the Thai Meteorological Department. The study area was divided into four regions, southern and Andaman, western, northern, and northeastern Thailand, to assess spatial differences in TEC behavior. Correlation analyses were performed between TEC anomalies, earthquake magnitudes, and geomagnetic activity measured by the Kp index. The results revealed that earthquakes with magnitudes below 5.0 Mw showed no significant correlation with TEC variations. However, for events with magnitudes equal to or greater than 5.0 Mw, a moderate negative correlation was found between earthquake magnitude and TEC anomalies, with correlation coefficients of –0.495, –0.501, and –0.303 for GPS TEC, IGS TEC, and IRI TEC, respectively. Typically, TEC values increased slightly approximately three to five days before an earthquake, then decreased sharply on the day of the event, and gradually returned to normal levels within three to five days afterward. Additionally, a positive correlation ($r = 0.611$) was observed between geomagnetic storm activity (Kp index) and large earthquakes. However, no direct relationship was found between geomagnetic disturbances and short-term TEC fluctuations on earthquake days.

The present study analyzes GNSS-derived TEC data to investigate ionospheric behavior preceding the Phitsanulok earthquake of 28 June 2023 (UT). The ROTI method was employed to detect potential pre-seismic irregularities and to characterize their temporal and spatial patterns, while geomagnetic storm conditions were examined to reduce the influence of external space-weather factors. To further assess short-term ionospheric disturbances, a statistical boundary approach based on the $\pm 2\sigma$ criterion was also applied. High-resolution TEC data from the UTHG GNSS station were evaluated over a 15-day reference interval (21 June–5 July 2023), during which the mean and standard deviation for each epoch (t) were derived from TEC values recorded at the same local time across all reference days. Instantaneous TEC deviations were then calculated, and anomaly thresholds were defined as $\mu \pm 2\sigma$, with values exceeding these limits classified as potential ionospheric anomalies. By integrating the ROTI technique with the $\pm 2\sigma$ statistical boundary method, the analysis improves the reliability of distinguishing seismo-ionospheric perturbations from normal diurnal and space-weather variations. This combined approach supports the evaluation of whether detectable TEC disturbances occurred before the event and enhances the understanding of lithosphere–ionosphere coupling processes, contributing to the development of more effective earthquake early-warning systems in Thailand.

III. RESEARCH METHODOLOGY

3.1 Geomagnetic storm data

Geomagnetic storm data were incorporated in this study to evaluate the influence of geomagnetic activity on ionospheric TEC variations during the earthquake period. The hourly equatorial Dst values were obtained from the World Data Center (WDC) for Geomagnetism, Kyoto, available at https://wdc.kugi.kyoto-u.ac.jp/dst_realtime/index.html. The data were collected from June 21 to July 5, 2023, corresponding to the analysis window of this study. This information was used to examine the relationship between geomagnetic storm conditions and

TEC behavior to distinguish whether observed TEC changes were caused by geomagnetic disturbances or by seismic activity. The geomagnetic storm data are presented in Figure 1.

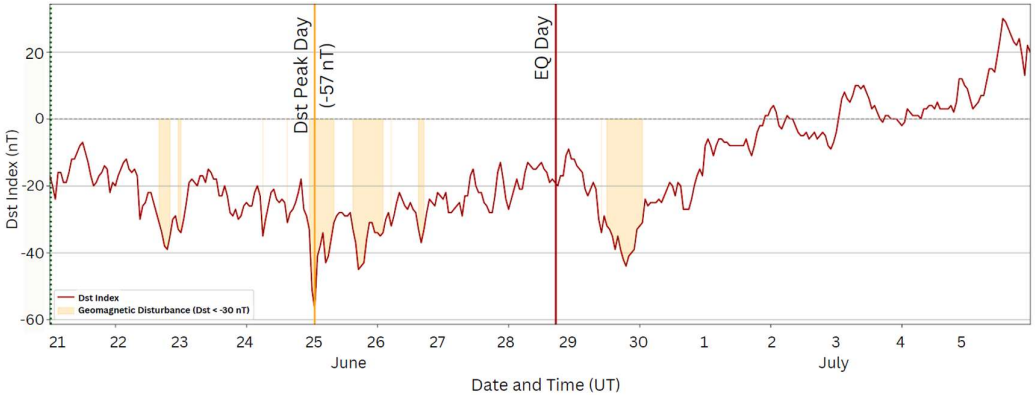

Figure 1: Geomagnetic storm with Dst index during June 21 to July 5, 2023

Figure 1 shows the temporal variation of the Dst index from June 21 to July 5, 2023 (UT). The highlighted yellow areas indicate periods of weak geomagnetic disturbances (Dst < –30 nT)

3.2 Earthquake data

On June 28, 2023 (17:17:56 UT), a moderate earthquake, recorded by the TMD as MLv 4.5, occurred in northern Thailand, located at 16.558° N and 100.368° E. Although the magnitude was relatively low compared to large-scale seismic events, the earthquake was shallow, at a depth of only 4.6 km, which increased ground shaking intensity in nearby areas. Such events are of particular interest because they may occur along previously unidentified or less-characterized fault zones. This underscores the importance of continuous monitoring and precise analysis of tectonic activity, even in regions not directly located on active plate boundaries.

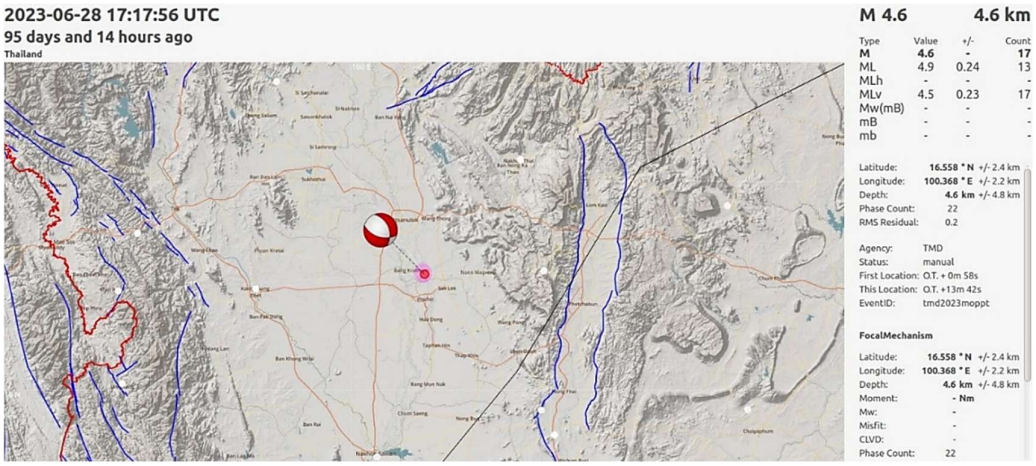

Figure 2: Seismic event map and focal mechanism of the earthquake on June 28, 2023 (UT)

Figure 2 indicates a predominantly strike-slip faulting mechanism, possibly with an oblique-slip component. The nodal planes, illustrated by the diagonally divided red and white quadrants, suggest right-lateral (dextral) motion along a southeast–northwest-trending fault. This fault orientation corresponds to the structural trend of the Phetchabun Mountain range, which lies east of the earthquake's epicenter.

3.3 The radius of the seismic epicentre area

Dobrovolsky et al. (1979, pp. 1025–1044) proposed a model to estimate the spatial extent of seismic influence by correlating earthquake magnitude with the radius of the affected area. The formulation as shown in Equation (1),

$$\rho = 10^{0.43M}, \tag{1}$$

here, the radius of the seismic epicenter area (ρ) in km is represented based on its magnitude (M).

This empirical relationship enables approximating the potential impact zone of significant seismic events by identifying regions likely influenced by precursory geophysical signals. The model further suggests that anomalies of varying physical origins, beyond ionospheric perturbations, can manifest within this calculated radius.

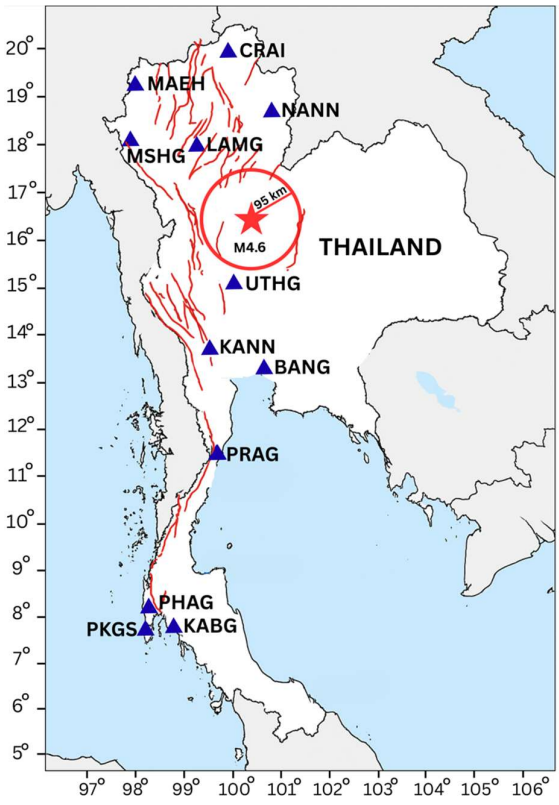

Figure 3: Epicentral location and affected radius of the June 28, 2023 (UT), earthquake in Northern Thailand

Figure 3, map of Thailand showing the epicenter (red star) of the MLv 4.5 or M 4.6 earthquake that occurred on June 28, 2023, UT, in the northern region of the country. The red circle indicates the estimated affected area with a radius of approximately 95 km, calculated using Dobrovolsky's empirical formula.GNSS stations (blue triangles) and fault lines (red lines) are also displayed to illustrate the tectonic framework and geodetic observation network relevant to this event. Earthquake parameters, including magnitude, epicentral coordinates, and depth, were obtained from the TMD GNSS station network. The data from the UTHG station in Uthai Thani Province (15.353° N, 100.009° E, elevation 27.991 m), the nearest station to the epicenter, were used as the primary reference for this study.

3.4 TEC estimation methodology using dual-frequency GPS observations

In this study, GPS-based TEC data were analyzed over 15 days, comprising seven days before and seven days after the seismic event. The TEC values (1 TECU = 10^{16} electrons/m²) were extracted from observation files in the Receiver Independent Exchange (RINEX) format, version 2.11. The slant TEC (STEC) was initially computed and then converted to Vertical TEC (VTEC) using a standard mapping function. The calculations were performed according to the procedure specified in Equations (2), (3), (4), and (5).

3.4.1 STEC

STEC was computed from carrier-phase observations at the L_1 and L_2 GPS frequencies, as outlined in prior studies (Ma & Maruyama, 2003, pp. 2083–2093; Kenpankho et al., 2011, pp. 365–370). These signals operate at frequencies of 1575.42 MHz (f_1) and 1227.60 MHz (f_2), corresponding to wavelengths of approximately 0.1902 m (λ_1) and 0.2442 m (λ_2), respectively. The relationship incorporates an ionospheric constant k of 80.62 m³/s².

$$STEC_L = \frac{2(f_1 f_2)^2}{k\left(f_1^2 - f_2^2\right)}\left[(L_1\lambda_1 - L_2\lambda_2) - (b_s + b_r)\right] \tag{2}$$

3.4.2 VTEC

VTEC was derived by converting STEC into a vertical equivalent under the assumption of a thin-shell ionospheric model. The transformation is expressed as follows:

$$STEC = \frac{VTEC}{\cos\chi}, \tag{3}$$

where χ denotes the zenith angle at the Ionospheric Piercing Point (IPP). The VTEC was further refined using an obliquity factor.

The χ is determined from the satellite elevation angle α using the following relation:

$$\chi = \arcsin\left(\frac{R_E \cos\alpha}{R_E + h}\right), \tag{4}$$

here, R_E represents the Earth's mean equatorial radius (6,378.134 km), and h denotes the height of the ionospheric shell (450 km) (Ma & Maruyama, 2003, pp. 2083–2093; Kenpankho et al., 2011, pp. 365–370). The elevation angles for estimating GPS TEC is 10 degrees to obtain VTEC with instrumental biases, as shown in Equation (5):

$$VTEC = (STEC - b_s - b_r) \times \cos \chi, \tag{5}$$

where b_s and b_r represent the satellite and receiver biases, respectively.

The estimated satellite and receiver biases were refined to improve accuracy. Based on the GPS Earth Observation Network (GEONET), an extensive GPS receiver network in Japan, Ma and Maruyama (2003, pp. 2083–2093) reported that satellite bias values typically range from 0.307 ns. For receiver bias estimation under quiet geomagnetic conditions, Kenpankho et al. (2021, p. 2157) recommended the use of the Lagrange interpolation method, with a receiver bias value of –6.25 ns.

3.5 Statistical boundary method for TEC anomaly detection

Additionally, statistical techniques were employed to define the boundary limits of TEC using the formula $\mu \pm 2\sigma$, following Ullah et al. (2025, p. 5). To further investigate the short-term TEC anomalies. To identify ionospheric anomalies, a statistical boundary method based on the ±2σ criterion was applied. High-resolution TEC data from the UTHG GNSS station were analyzed over a 15-day reference period (June 21–July 5, 2023). For each epoch (t), the mean (μ) and standard deviation (σ) of TEC were computed from the same local time across all 15 days. The instantaneous anomaly was then determined as:

$$\Delta TEC(t) = TEC_{obs}(t) - \mu(t) \tag{6}$$

The UB and LB statistical limits were defined as:

$$UB(t) = \mu(t) + 2\sigma(t), \quad LB(t) = \mu(t) - 2\sigma(t) \tag{7}$$

A deviation beyond ±2σ was classified as an anomalous TEC variation, representing approximately a 95% confidence level under quasi-Gaussian distribution assumptions. This approach enables the detection of significant departures from normal ionospheric behavior.

3.6 ROTI

The ROTI is calculated as the standard deviation of the Rate of TEC (ROT) over a specific time window, expressed in TECU/min (Pi et al., 1997, pp. 2283–2286):

$$ROTI = \sqrt{\langle ROT^2 \rangle - \langle ROT \rangle^2} \tag{6}$$

The ROT represents the first-order difference of consecutive TEC values normalized by the time interval Δt (in minutes). TEC values are given in TECU. ROTI values were computed using a 5-minute sliding window to represent short-term ionospheric irregularities.

$$ROT_i = \frac{TEC_i - TEC_{i-1}}{\Delta t} \quad (7)$$

3.7 Global TEC

To validate the accuracy and consistency of the calculated TEC values, a comparison was made with Global TEC data. The global TEC maps were obtained from the GNSS TEC database, accessible via the following link: https://stdb2.isee.nagoya- u.ac.jp/GPS/GPS-TEC/GLOBAL/AMAP/index.html#2023. This comparison aimed to verify whether the computed TEC values aligned with global trends and exhibited similar temporal and spatial patterns.

IV. RESULTS

4.1 Relationship between geomagnetic storm intensity and TEC anomalies

Table 1 presents the daily correlation coefficients (r) (Mukaka, 2012, pp. 69–71) between the Dst index and TEC anomalies to assess the influence of geomagnetic conditions on ionospheric variations during the study period as shown in Table 1.

Table 1: Daily correlation coefficients between geomagnetic activity (Dst index) and TEC anomalies from June 21 to July 5, 2023

Date (UT)	Correlation coefficients (r)	Interpretation	Note
2023-06-21	0.3559	Low, positive correlation	
2023-06-22	−0.3590	Low, negative correlation	
2023-06-23	−0.2059	Negligible correlation	Five days before EQ
2023-06-24	−0.0350	Negligible correlation	
2023-06-25	−0.5070	Moderate, negative correlation	Peak Dst day
2023-06-26	−0.0044	Negligible correlation	
2023-06-27	−0.0838	Negligible correlation	
2023-06-28	0.0833	Negligible correlation	EQ day
2023-06-29	−0.0590	Negligible correlation	
2023-06-30	−0.3638	Low, negative correlation	
2023-07-01	0.1066	Negligible correlation	
2023-07-02	−0.4094	Low, negative correlation	
2023-07-03	−0.8087	High, negative correlation	
2023-07-04	−0.0332	Negligible correlation	
2023-07-05	0.3903	Low, positive correlation	

Most days exhibited negligible correlations, suggesting that geomagnetic activity had minimal impact on TEC fluctuations. A moderate negative correlation (r = –0.507) was observed on June 25, corresponding to the peak Dst disturbance day, while on the earthquake day (June 28), the correlation was negligible (r = 0.0833) (Mukaka, 2012, pp. 69–71). These results indicate that the ionospheric TEC variations near the time of the earthquake were unlikely to be dominated by geomagnetic storm effects.

4.2 TEC anomalies

This study aimed to investigate the TEC anomalies preceding the MLv 4.5 earthquake that occurred in Thailand on June 28, 2023. By analyzing 1-second-interval TEC data from June 21 to July 5, 2023, and applying statistical boundary-detection methods, we identified potential ionospheric precursors that deviated significantly from normal diurnal variations. The figure below illustrates these anomalies and highlights their temporal relationships with the earthquake events.

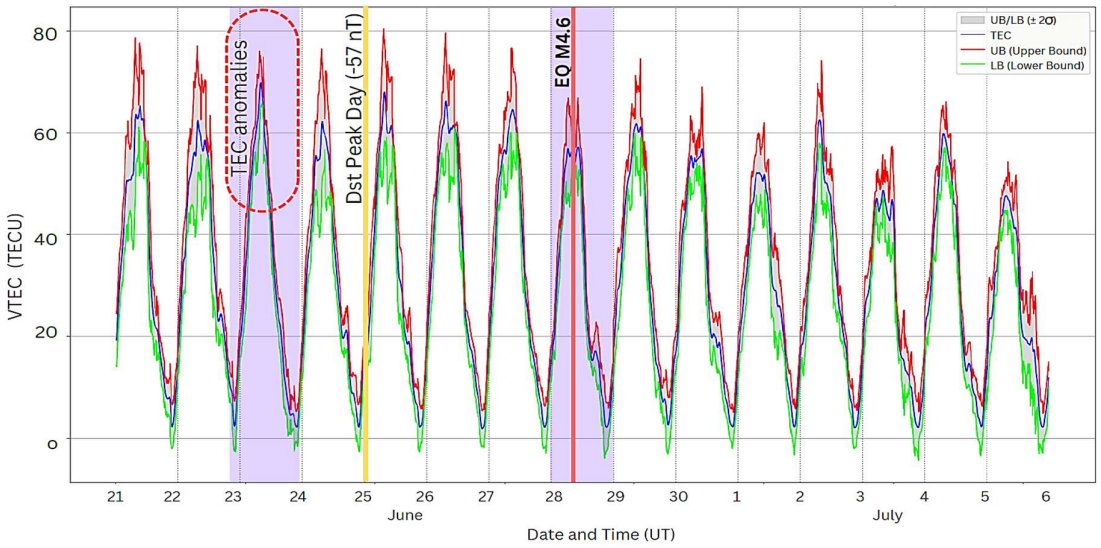

Figure 3: TEC anomalies associated with the MLv 4.5 earthquake on June 28, 2023

The time series of TEC at 1-second intervals from the UTHG station was analyzed to identify potential ionospheric precursors, with ΔTEC defined as the difference between the observed TEC and the 15-day mean TEC. Figure 3 presents the TEC variations observed from June 21 to July 5, 2023 (UT), showing the observed TEC (blue), UB (red), and LB (green). The shaded purple regions indicate significant TEC anomalies that exceeded the established statistical limits (UB and LB), most notably on June 23, 2023, approximately five days before the earthquake. An anomalous increase of about 2.61 TECU above the 15-day mean was recorded on June 23, followed by a marked decrease in TEC on the day of the earthquake (June 28, 17:17:56 UT). Thereafter, the TEC gradually returned to normal levels within four to five days. This sequence of enhancement, depletion, and recovery suggests the presence of a short-term ionospheric disturbance potentially associated with the seismic event, rather than regular ionospheric variability. The observed patterns support the hypothesis that pre-seismic TEC anomalies may serve as ionospheric precursors to moderate earthquakes in low-latitude regions such as Thailand.

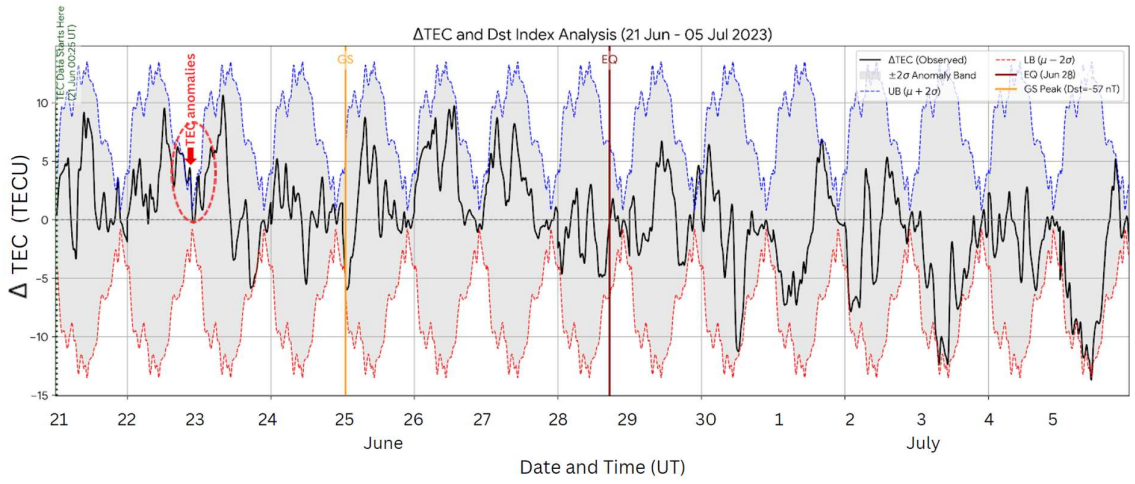

Figure 4: Time series of TEC variations and Dst index from June 21 to July 5, 2023

Figure 4 (upper panel) shows the temporal variation in ΔTEC from June 21 to July 5, 2023. The black line represents observed ΔTEC values, with the gray band indicating the normal range (±2σ). Vertical lines mark the geomagnetic storm peak (GS peak, June 25; Dst = –57 nT) and the earthquake day (EQ, June 28; MLv 4.5). The lower panel displays the hourly Dst index. Periods with Dst < –30 nT (orange zones) indicate geomagnetic disturbances, notably the drop on June 25. On the day of the earthquake, the Dst index remained stable, indicating quiet geomagnetic conditions during the event. Overall, the ΔTEC plot shows fluctuations near the ±2σ threshold approximately three to five days before the earthquake, while the Dst index remained within non-disturbed levels. This suggests that the TEC anomalies observed before the event were unlikely to be influenced by geomagnetic activity and may instead be associated with pre-seismic ionospheric perturbations.

4.3 ROTI variations

The ionosphere is sensitive to perturbations from both terrestrial and space weather influences and often exhibits detectable variations in TEC before large earthquakes. Among the key indicators of such disturbances are sudden enhancements in VTEC, fluctuations in STEC, and abrupt changes in ROTI, which reflect small-scale plasma irregularities. This study focuses on two critical dates, June 23 and June 28, 2023(UT), surrounding an MLv 4.5 earthquake. TEC parameters were extracted from the GNSS observations at the UTHG station to identify potential ionospheric signatures.

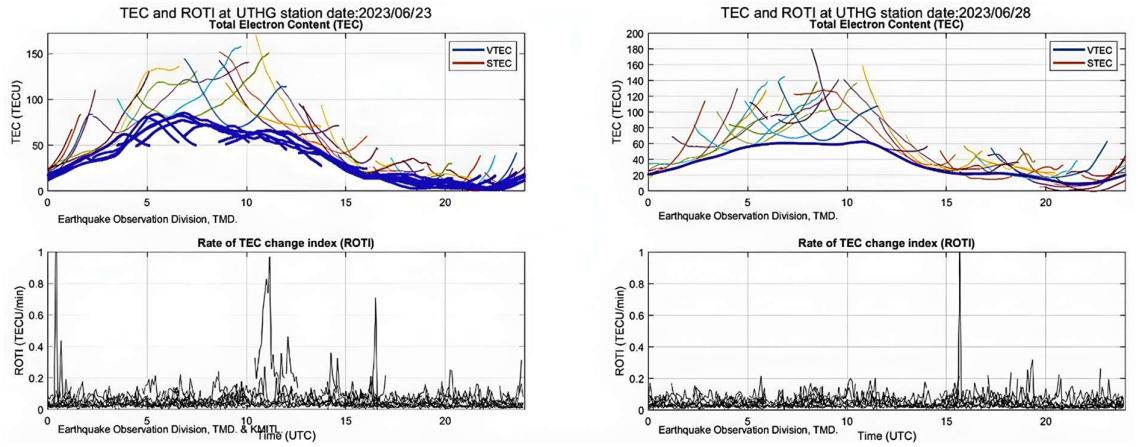

Figure 5: Daily variations of VTEC, STEC, and ROTI at the UTHG station on June 23 and June 28, 2023 (UT)

Figure 5 presents the daily variations of VTEC, STEC, and ROTI at the UTHG station on two representative days, June 23 (left) and June 28 (right), 2023. The upper panels show VTEC and STEC trends throughout the day, highlighting enhanced ionospheric activity on June 23 and a localized TEC reduction on June 28. The lower panels illustrate the ROTI values, derived at one-minute intervals to capture short-term ionospheric fluctuations. On June 23, variations in ROTI were observed between 10:00 and 16:00 UT, lasting for several hours. In contrast, on June 28, a sharp and short-lived ROTI spike occurred around 16:00 UT, closely coinciding with the earthquake time (17:17:56 UT). This spike, lasting only a few minutes, was detected under quiet geomagnetic conditions (Dst > –30 nT) and was absent during the geomagnetic storm on June 25 (Dst ≈ –57 nT). ROTI was calculated using a 5-minute sliding window (units: TECU/min). Since EIA-related scintillation typically persists for tens of minutes to hours after sunset, the brief and localized nature of the June 28 ROTI anomaly, combined with the absence of widespread regional disturbances, suggests that it was unlikely to result from routine EIA or space-weather effects. Instead, this transient feature likely reflects a localized ionospheric disturbance potentially associated with the seismic event. Both days were analyzed using the same GNSS data-processing approach. The comparison between June 23 and June 28 was intended to emphasize differences in the temporal behavior of VTEC rather than to perform a direct numerical comparison, ensuring that the observed distinctions represent genuine ionospheric variability rather than methodological bias.

4.4 Global TEC anomalies

Global TEC data were incorporated as a reference to validate the reliability of TEC values obtained from the ground-based UTHG station. This comparison ensured the consistency and accuracy of locally derived TEC, confirming that the observed variations reflected genuine ionospheric behavior rather than instrumental or processing errors. The study utilized global ionospheric TEC maps derived from GNSS-TEC observations to assess the spatiotemporal variability of TEC across Southeast Asia, with a particular focus on Thailand. The analysis covered the period from June 21 to July 5, 2023 (UT), encompassing the MLv 4.5 earthquake that occurred in northern Thailand on June 28. In Figure 6, a visual inspection of the daily

global TEC maps revealed elevated TEC over Thailand on June 23, followed by a noticeable decrease on June 28, coinciding with the earthquake. These patterns suggest the presence of possible ionospheric anomalies preceding the seismic event. The global TEC dataset was primarily used to identify large-scale ionospheric trends and to verify that regional TEC variations derived from the UTHG station were consistent with broader ionospheric behavior across the region. The purpose of this comparison was not to conduct a direct quantitative analysis but to confirm that the TEC anomalies observed over Thailand aligned with global ionospheric conditions reported by established international databases.

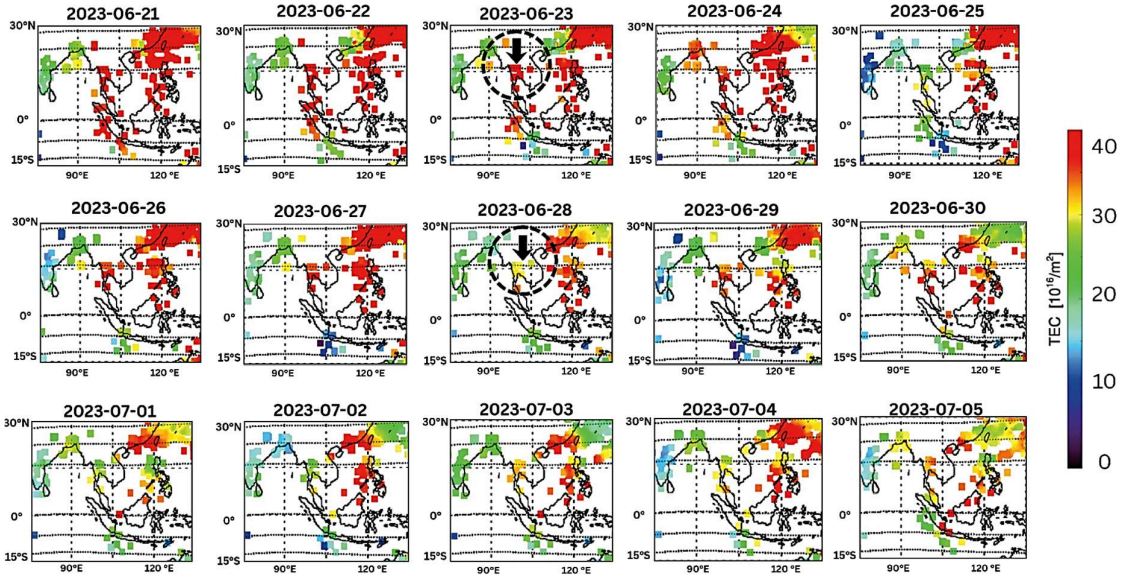

Figure 6: Global TEC maps over Thailand from June 21 to July 5, 2023

The maps in Figure 6 illustrate the spatial distribution of ionospheric TEC over Southeast Asia, with a particular focus on Thailand, outlined by a dashed black line. On June 23, five days before the MLv 4.5 earthquake, a distinct enhancement in TEC was observed over the region of interest, deviating noticeably from adjacent days. Conversely, on June 28, the day of the earthquake, a localized depletion in TEC was observed over northern Thailand, coinciding with the epicenter of the seismic event. The black circle marks the approximate earthquake location, while the black arrows indicate the regions exhibiting significant TEC variations. These anomalies suggest possible ionospheric responses linked to lithospheric processes preceding the seismic event. The TEC levels are color-coded, with higher values represented in red and lower values in blue, enabling clear visual comparison of ionospheric conditions throughout the 15-day study period.

V. CONCLUSION AND DISCUSSION

The findings of this study support the evidence that ionospheric TEC anomalies can serve as short-term precursors to seismic events. A distinct TEC enhancement of approximately 2.61 TECU was detected on June 23, 2023, five days before the MLv 4.5 earthquake in Northern Thailand on June 28, 2023, followed by a marked depletion on the day of the event. These fluctuations exceeded the ±2σ statistical boundaries, indicating statistically significant deviations from the mean trend and suggesting a possible seismo-ionospheric coupling. Complementary analyses further reinforce these findings. The ROTI results revealed a brief and localized fluctuation around 16:00–17:00 UT on the earthquake day, closely coinciding with the seismic occurrence, while geomagnetic activity remained quiet (Dst > −30 nT). In addition, the global TEC maps showed a consistent spatial pattern, with elevated TEC over Thailand on June 23 and an apparent depletion on June 28. Overall, the consistency between the local and global observations indicates that the detected ionospheric anomalies are unlikely to have resulted from regular geomagnetic or solar effects. Instead, they may reflect localized ionospheric perturbations potentially linked to pre-seismic lithospheric processes. These results highlight the potential of GNSS-based ionospheric monitoring as a valuable tool for short-term earthquake forecasting in low-latitude regions such as Thailand.

This fluctuation pattern is reminiscent of the results reported by Xia et al. (2011, pp. 177–185), who identified two phases of TEC increase occurring approximately 9 and 2–3 days before seismic events and a subsequent decline 3–6 days prior, all of which were found to be independent of geomagnetic disturbances. Similarly, Heki (2011, pp. 1–5) identified a distinct positive TEC anomaly roughly 40 minutes before the 2011 Tohoku-Oki earthquake (Mw 9.0), findings that mirror observations from the 2010 Chile and 2004 Sumatra–Andaman earthquakes. Cahyadi and Heki (2013, pp. 1777–1787) also reported both co-seismic and pre-seismic TEC anomalies for the 2007 Bengkulu and 2005 Nias earthquakes, though longer-term precursors were not consistently evident. On a broader scale, Shah and Jin (2015, pp. 42–49) conducted a global analysis of 1,492 seismic events (Mw ≥ 5.0), revealing that TEC values often rose significantly within five days preceding shallow earthquakes (depth < 60 km) with magnitudes Mw ≥ 6.0. In addition, Grawe and Makela (2015, pp. 472–483) explored ionospheric responses triggered by tsunamis following the 2010 Chile, 2011 Tohoku, and 2012 Haida Gwaii earthquakes, highlighting the impact of propagation direction and satellite geometry. In a study focused on the Himalayan region, Sharma et al. (2017, pp. 65–74) modeled TEC behavior using GNSS data. They emphasized the importance of mitigating the effects of solar and geomagnetic influences when interpreting pre-seismic anomalies. Ulukavak and Inyurt (2020, pp. 123–130) observed that disturbances in the ionosphere may persist for up to 15 days before an earthquake and for up to two weeks after. Similarly, Kiyani et al. (2020, pp. 1–8) reported mild TEC fluctuations up to 10 days before the 2018 Fiji earthquake (Mw 8.2), which could be distinguished from the post-seismic geomagnetic signals. Nishioka et al. (2021, pp. 1–12) contributed by defining statistical thresholds for abnormal TEC behavior based on two decades of GNSS observations in Japan, aiding in the reliable detection of unusual patterns. Guo et al. (2022, pp. 1–17) found consistent increases in TEC in Taiwan 13 to 20 days before earthquakes, even during periods of low geomagnetic activity. Recently, Semlali et al. (2025, pp. 7589–7609) analyzed more than 200,000 seismic events globally using satellite observations from Swarm A, B,

and C. Their analysis incorporated UbRMSD, CM, and ROC methods to identify anomalies in TEC and MFV-Y. Their results revealed that these anomalies commonly emerged one to seven days before earthquakes, especially those with Mw ≥ 7.0, although the presence of background ionospheric noise continues to present detection challenges. Collectively, these studies, along with our findings, underscore the potential of TEC anomalies as reliable short-term precursors to seismic activity. However, interpreting such anomalies must be carefully contextualized, accounting for geomagnetic, solar, and atmospheric influences, to minimize false positives and improve forecasting reliability.

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THE DEVELOPMENT OF OUTDOOR ELECTRICAL INSTALLATION SKILLS THROUGH MIAP LEARNING MODEL COMBINED WITH SIMULATION-BASED LEARNING FOR VOCATIONAL CERTIFICATE STUDENTS IN LOPBURI TECHNICAL COLLEGE

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ABSTRACT

This study aimed to develop a learning management model that integrates the MIAP model with simulation-based learning for vocational certificate students in Lopburi Technical College. The sample included 19 third-year Electrical Power students from Lopburi Technical College enrolled in the Outdoor Electrical Installation subject during semester 2/2024, who were selected by cluster random sampling. The research instruments follow: 1) the learning model integrating the MIAP model with simulation-based learning, 2) an instructional package for outdoor electrical installation, which consists of a teacher's manual, instructional plans, presentation media, and activity sheets, 3) the learning achievement test, 4) an outdoor electrical installation skill assessment form, and 5) the students' satisfaction evaluation form. The statistical methods used in this study included percentage, mean, standard deviation, and t-test (dependent). The study found that: 1) The developed instructional model, which integrates the MIAP learning model with Simulation-Based Learning (SBL), was of high quality ($\bar{x}$ = 4.34, SD = 0.37), 2) students showed significantly higher learning achievement after learning through the integrated learning model ($p < .05$), 3) students who learned through the developed instructional model showed high outdoor electrical installation skills (average score was 3.15

or 78.82%) and 4) students showed a highest level of satisfaction with the developed instructional model ($\bar{x}$ = 4.51, SD. = 0.30), thus the integrated model helps vocational students develop practical skills and a deeper understanding through active learning, real-life practice, and continuous reflection.

Keywords: MIAP learning model, Simulation-based learning, Vocational certificate, Development of outdoor electrical installation skills

I. INTRODUCTION

According to the Twelfth National Economic and Social Development Plan (2023–2027), Thailand must prioritize the advancement of science, technology, research, and innovation as essential drivers for enhancing national competitiveness. At the same time, it is critical to accelerate the upskilling of the workforce, especially among new entrants to the labour market (Office of the National Economic and Social Development Council, 2023). In alignment with this direction, the Strategic Policies of the Office of the Vocational Education Commission (2012–2026) emphasize the production and development of manpower that meets national demands in industrial, economic, and social sectors. One area of focus is the development of vocational education to ensure that graduates possess the practical skills required by employers. In the field of electrical power, one critical skill is outdoor electrical installation, which requires both technical precision and hands-on experience. However, conventional teaching methods that rely mainly on lectures and demonstrations may fall short in equipping students with real-world competencies and confidence.

Several previous studies have pointed out the limitations of classroom-based instruction in vocational training. Poopamonkaipob (2019, pp. 14–21) emphasized that most vocational students have few opportunities to practice in settings that closely simulate actual workplaces, resulting in limited problem-solving skills and confidence. Similarly, Phoyen (2021, pp. 11–28) found that while students receive some technical instruction, the lack of practical exposure hampers their ability to transfer knowledge to real work conditions. These findings highlight the need for innovative instructional approaches that promote hands-on experience and engagement with real-life scenarios. To meet this demand, simulation-based learning has emerged as a valuable method for developing job-ready skills. However, additional strategies are still needed to structure such learning experiences effectively.

One such strategy is the MIAP learning model, which consists of four components: Motivation, Information, Application, and Progress. This model promotes active learning by encouraging students to participate meaningfully in each stage of the learning process (Phetjan et al., 2023, pp. 1–14). A key strength of the MIAP model lies in its structured and progressive approach, which enhances understanding and performance. When combined with simulation-based learning, it helps replicate realistic working conditions and provides learners with repeated opportunities for skill development. As Chudjuajeen et al. (2021, pp. 149–163) suggested, simulation-based approaches allow students to perform tasks in safe, practice-based environments that reflect actual job scenarios. The integration of MIAP with simulation thus serves as a promising solution to bridge the gap between theoretical instruction and practical application in vocational education.

Therefore, the objective of this research is to develop a learning management model that integrates the MIAP learning model with simulation-based learning (SBL) for vocational students in outdoor electrical installation skills. This study aims to enhance students' learning outcomes by offering experiences that combine theoretical knowledge with hands-on practice, ultimately fostering analytical thinking, problem-solving ability, and confidence to perform tasks effectively and safely in real-world environments.

II. LITERATURE REVIEW

The MIAP learning model (Tongrot & Pansri, 2022, pp. 188-201) is a student-centred approach that encourages active engagement through four key stages: 1) Motivation (M): Instructors stimulate interest using media such as videos, images, or Q&A, helping learners connect prior knowledge to new content through real-world problems, 2) Information (I): This step is to convey knowledge or the essence of the lesson. The teacher must clearly explain the scope of the content so that the learners can prepare and plan their learning appropriately, 3) Application (A): Learners practice applying knowledge through hands-on tasks, exercises, or simulations that align with learning goals, helping reinforce understanding and build skills, 4) Progress (P): Learner performance is assessed through participation and task completion. Simulation-Based Learning (SBL) (Alharbi et al., 2024, pp. 1-21) is an instructional approach that places learners in realistic environments where they take on assigned roles under specific conditions. It allows students to practice problem-solving and critical thinking through direct experience in settings that resemble real-life situations. The key outcomes of SBL include (Khumsuk & Nillapun, 2021, pp. 1-11): 1) Knowledge acquisition aligned with learning goals and hands-on experiences, 2) Learner satisfaction, which reflects how students respond to the learning process and environment, and 3) Self-confidence, which directly influences the quality of performance. Simulation-Based Learning (SBL) helps boost learners' confidence, especially in performing technical tasks and making informed decisions. The learning process is typically organized into four stages (Chubkhuntod et al., 2020, pp. 1062-1072): 1) the provision of concrete experiences, 2) reflection on those experiences, 3) the development of abstract concepts derived from observations, and 4) the application of those concepts in new situations.

To address the need for effective instructional strategies in vocational education, several studies have proposed integrating active learning with simulation-based approaches. Informed by these developments, the present study combines the MIAP learning model, comprising four stages: Motivation, Information, Application, and Progress, with Simulation-Based Learning (SBL) to design an instructional framework aimed at enhancing outdoor electrical installation skills among vocational students. The hypothesis is that innovation-based learning activities, which integrate hands-on practice with analytical thinking, can significantly improve academic achievement, vocational skill performance, and student satisfaction.

III. RESEARCH METHODOLOGY

This section outlines the research methodology employed in the study, which aimed to develop and evaluate an instructional model that integrates the MIAP learning model with simulation-based learning (SBL) to enhance vocational students' outdoor electrical installation skills. The section includes the research design, conceptual framework, participants, research instruments, model development process, data collection procedures, and statistical analysis, with the details as follows:

3.1 Conceptual Framework

The conceptual framework of this study, which focuses on developing outdoor electrical installation skills through the integration of the MIAP learning model and simulation-based learning for vocational certificate students, consists of the independent variable: MIAP learning model combined with simulation-based learning, which consists of Motivation, Information, Application, and Progress. The dependent variables: learning achievement, outdoor electrical installation skills, and learner satisfaction, as illustrated in Figure 1.

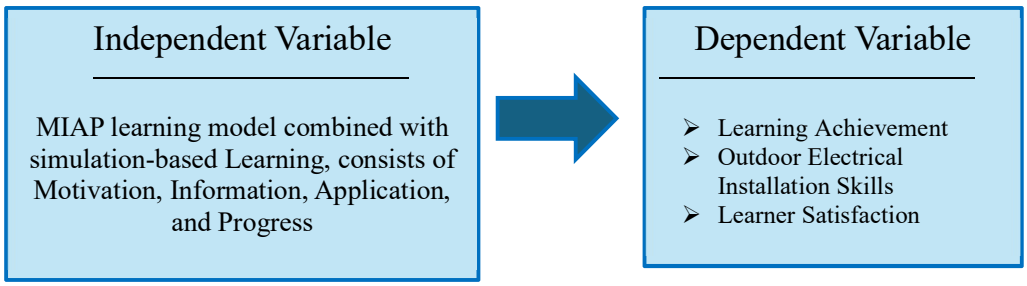

Figure 1: Independent variable and dependent variable in research

3.2 Research Design

This study employed a one-group pretest–posttest experimental design (Seetao et al., 2025, pp. 277-297), which is appropriate for evaluating the effectiveness of an instructional intervention when only a single group is available for study. In this design, participants were assessed before and after receiving instruction using the developed model to measure changes in key outcomes. The instructional model, which integrates the MIAP learning model with simulation-based learning (SBL), was applied in a real classroom setting. The design involved three main phases: 1) administering a pre-test to determine academic performance, 2) implementing the instructional model through a sequence of learning activities aligned with the MIAP learning model with simulation-based learning (SBL) principles, and 3) conducting a post-test using the same assessment instruments to evaluate improvements in academic achievement and student satisfaction.

3.3 Population and Sample

The population in this study consisted of 93 third-year vocational certificate students in the Electrical Power Program at Lopburi Technical College who were enrolled in the "Outdoor Electrical Installation" course during the second semester of the 2024 academic year. These students were distributed across five classrooms

The sample group in this study consisted of 19 third-year vocational certificate students in the Electrical Power Program at Lopburi Technical College. The students were enrolled in the Outdoor Electrical Installation course during the second semester of the 2024 academic year and were selected from a total population of 93 students distributed across five classrooms. The selection was made using cluster random sampling (Mingolo, 2025, pp. 82-98) by choosing one classroom.

3.4 Research Instruments

The research instruments used in the development of outdoor electrical installation skills through the MIAP learning model, combined with simulation-based learning for vocational certificate students, are illustrated in Figure 2 and described as follows:

1) A learning model integrating the MIAP model with simulation-based learning, designed to enhance students' skills in outdoor electrical installation,

2) An instructional package for outdoor electrical installation consists of a teacher's manual, instructional plans, presentation media, and activity sheets.

3) A learning achievement test comprising 60 multiple-choice questions with four answer choices, developed to assess students' academic performance which the content validity of the test items was evaluated using the Index of Item-Objective Congruence (IOC), with all items scoring above 0.50.

4) An outdoor electrical installation skill assessment form, which is an Analytic rubric-based assessment form with four scoring levels. (Sukmak & Klinbumrung, 2025, pp. 1-10)

5) The students' satisfaction evaluation form with the developed teaching model used a 5-point Likert scale (Yuangngoen et al., 2019, pp. 50-58).

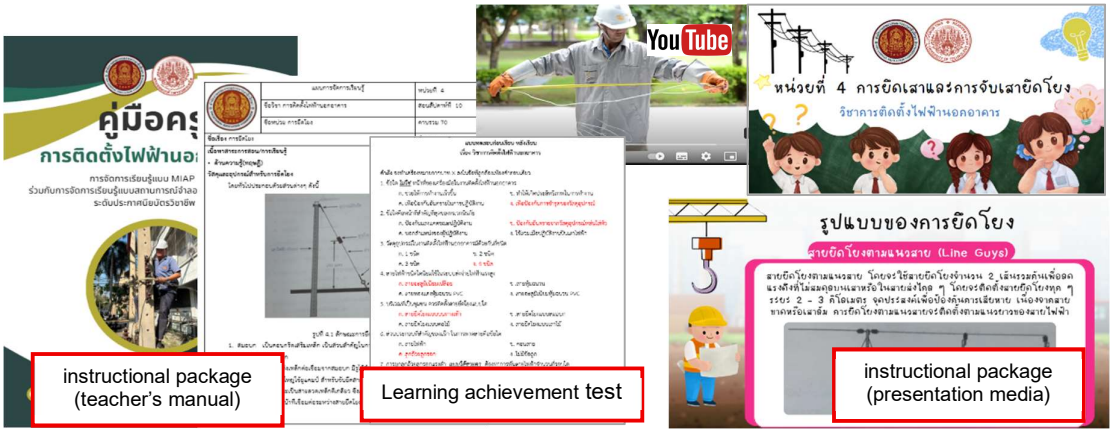

Figure 2: Examples of research instruments

3.5 Research Procedure

3.5.1 The study began with the collection of essential data, including: 1) the course description of 20104-2012 Outdoor Electrical Installation, and 2) the instructional plans designed using the MIAP learning model integrated with simulation-based learning, focusing on practical skill development in the subject of outdoor electrical installation.

3.5.2 Development of a learning management model. The integration of the two instructional approaches enables learners to connect theoretical knowledge with practical application, while enhancing analytical thinking skills and self-confidence. This is particularly suitable for skill-based subjects such as outdoor electrical installation. The MIAP learning model consists of four stages: 1) Motivation, 2) Information, 3) Application, and 4) Progress, emphasizing active learner engagement throughout the process. Similarly, simulation-based learning comprises four key steps: 1) the provision of concrete experiences, 2) reflection on those experiences, 3) the development of abstract concepts derived from observations, and 4) the application of those concepts in new situations, as illustrated in Figure 3. Designing learning activities that combine both approaches can enhance realism in instruction and ensure alignment with real-world work environments, as shown in Table 1, which presents the instructional process based on the integrated model.

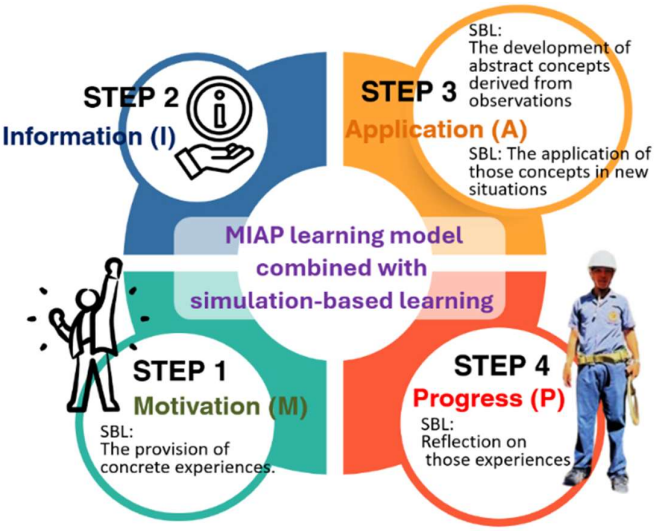

Figure 3: The developed MIAP learning model combined with Simulation-Based learning

Table 1: The instructional process based on the learning model

MIAP learning process	Simulation-based learning process	Training and learning activities
1. Motivation (M)	Step in the provision of concrete experiences.	Instructor - Provided an overview of the learning agreement and classroom expectations. - Introduced the lesson using a video that simulated a real-world scenario, such as an outdoor electrical malfunction. Students - Attentively listened to the instructor and asked clarifying questions as needed.

Table 1: (Continued) The instructional process based on the learning model

MIAP learning process	Simulation-based learning process	Training and learning activities
1. Motivation (M)	Step in the provision of concrete experiences.	Instructor - Provided an overview of the learning agreement and classroom expectations. - Introduced the lesson using a video that simulated a real-world scenario, such as an outdoor electrical malfunction. Students - Attentively listened to the instructor and asked clarifying questions as needed.
2. Information (I)		Instructor - Delivered relevant theoretical content to provide learners with foundational knowledge before engaging in practice. - Demonstrated the practical tasks based on the activity sheet. Students - Listened to the instructional content attentively.
3. Application (A)	Step in the development of abstract concepts derived from observations. Step in the application of those concepts in new situations.	Instructor - Designed challenging simulation scenarios to encourage problem-solving. - Observed students' performance during the activity. Students - Planned and applied problem-solving strategies. - Independently performed tasks within the simulated scenario.
4. Progress (P)	Step in reflection on those experiences	Instructor - Provided constructive feedback on students' performance. - Facilitated knowledge sharing and reflection based on practical experiences. Students - Engaged in peer discussion and shared insights from their practice. - Analyzed the strengths and weaknesses of their performance to enhance future learning.

3.5.3 The developed MIAP learning model, combined with simulation-based learning, was designed to improve outdoor electrical installation skills for vocational certificate students. The quality of the model was evaluated by five experts who had at least five years of teaching experience in higher education and knowledge in education or electrical-related fields. The model was then revised based on their suggestions.

3.5.4 The instructional activities were implemented based on the MIAP learning model combined with simulation-based learning, following a preliminary experimental research design. A one-group pretest–posttest design was employed with a sample of 19 students from the Electrical Power Program at Lopburi Technical College during the second semester of the 2024 academic year.

3.5.5 The students' learning achievement was compared before and after the implementation of the developed MIAP learning model combined with simulation-based learning. A 60-item multiple-choice test with four answer options was used as the assessment tool.

3.5.6 The students' outdoor electrical installation skills were assessed through practical activities based on the developed MIAP learning model with a simulation-based learning (SBL) using a four-level analytic rubric evaluation form.

3.5.7 Students' satisfaction with the developed MIAP learning model combined with simulation-based learning was assessed using a questionnaire based on a 5-point Likert scale. After that, data were collected, analyzed using appropriate educational statistics, and summarized to conclude.

3.6 Data Analysis

Data analysis in this study consisted of four parts: 1) the quality evaluation of the developed MIAP learning model combined with simulation-based learning was analyzed using mean and standard deviation, 2) the students' learning achievement before and after the implementation of the instructional model was compared using a dependent-samples t-test, 3) the outdoor electrical installation skills were analyzed by comparing percentage scores and 4) the students' satisfaction with the developed instructional model was analyzed using mean and standard deviation.

IV. RESULTS

4.1 Results of the Learning Model Quality Evaluation

The quality of the developed instructional model was evaluated by five experts in the field of electrical and electronic education, each with more than five years of teaching experience, as shown in Table 2.

Table 2: Results of the learning model quality evaluation (n=5)

Item	$\bar{x}$	SD	Interpret
1. Instructional design and structure.	4.32	0.33	high
2. Learning activities	4.52	0.46	highest
3. Applicability and practical relevance	4.36	0.48	high
4. Measurement and evaluation	4.16	0.30	high
Total average	4.34	0.37	high

For Table 2 as the results revealed that the overall quality of the learning model was rated at a high level ($\bar{x}$ = 4.34, SD = 0.37). Specifically, the mean scores for each aspect were as follows: instructional design and structure ($\bar{x}$ = 4.32, SD = 0.33), learning activities ($\bar{x}$ = 4.52, SD = 0.46), applicability and practical relevance ($\bar{x}$ = 4.36, SD = 0.48) and measurement and evaluation ($\bar{x}$ = 4.16, SD = 0.30).

In addition, the experts recommended improving the clarity of the instructional activity plans to ensure that teachers can implement them more easily, incorporating more diverse assessment tools, such as using behavioral observation forms alongside student self-assessment. All suggestions were incorporated into the model before it was implemented in the actual experiment.

4.2 Results of the comparison of students' learning achievement

To assess the effectiveness of the developed instructional model, a pre-test and post-test were administered to a sample group of 19 vocational certificate students. The test consisted of 60 multiple-choice questions as shown in Table 3.

Table 3: Results of the comparison of students' academic achievement (n=19)

Test	Score	$\bar{x}$	SD	df	t_{cal}	Sig. (1 tailed)
Pretest	60	30.79	5.34	18	12.02*	0.0000
Posttest	60	48.68	6.52			

$p < .05$, one-tailed

For Table 2, the mean pre-test score was 30.79 (SD = 5.34), while the mean post-test score increased to 48.68 (SD = 6.52). A paired-samples t-test indicated a statistically significant difference at the .05 level ($t = 12.02$, $p < .05$), confirming the effectiveness of the instructional model.

4.3 The Results of Developing Outdoor Electrical Installation Skills

To evaluate the effectiveness of the instructional model that integrated the MIAP approach with simulation-based learning, an assessment was conducted focusing on ten core competencies related to outdoor electrical installation. The evaluation measured students' performance using a 4-point rubric score, as shown in Table 4.

Table 4 : The results of outdoor electrical installation skills

Item	$\bar{x}$ value (max 4 points)	Performance (100%)	Rank
1. Wearing appropriate personal protective equipment.	3.63	90.79	1
2. Using tools and equipment for tasks on utility poles.	3.58	89.47	2
3. Climbing and performing tasks on utility poles safely.	3.53	88.16	3
4. Assessing the work environment prior to operation.	2.95	73.68	7
5. Inspecting and testing electrical systems.	3.26	81.58	5
6. Securing guy wires appropriately	3.11	77.63	6
7. Installing rack channels.	2.84	71.05	8
8. Installing low-voltage insulators	2.68	67.11	9

Table 4: (Continued) The results of outdoor electrical installation skills

Item	$\bar{x}$ value (max 4 points)	Performance (100%)	Rank
9. Installing high-voltage insulators	2.53	63.16	10
10. Working in compliance with safety standards and legal regulations	3.42	85.53	4
Total average	**3.15**	78.82	

According to Table 4, the strengths are wearing appropriate personal protective equipment, using tools and equipment for tasks on utility poles, and climbing and performing tasks on utility poles safely, respectively. The weaknesses are installing high-voltage insulators and installing low-voltage insulators, respectively. The overall mean score of students' outdoor electrical installation skills was 3.15, with a score over 70 percent interpreted as a "high" level. showing a need for further practice in these complex tasks.

4.4 Students' Satisfaction with the Learning Model

Students' satisfaction with the integrated learning model, combining the MIAP learning model with simulation-based learning, was evaluated through a structured questionnaire administered at the end of the instructional program. The questionnaire consisted of Likert-scale items covering key aspects, as shown in Table 5.

Table 5: Students' satisfaction with the learning model (n=19)

Item	$\bar{x}$	SD	Interpret	Rank
1. Activities were well-structured and easy to follow.	4.47	0.51	high	4
2. The model encouraged active teacher-student and peer interaction.	4.42	0.61	high	5
3. Content was effectively connected to real tasks.	4.37	0.50	high	6
4. Simulations increased motivation and engagement.	4.68	0.48	highest	1
5. Students applied knowledge to problem-solving.	4.58	0.69	highest	3
6. Learners practised self-monitoring and metacognition.	4.47	0.61	high	4
7. The environment boosted enthusiasm for learning.	4.58	0.51	highest	3
8. Teamwork and collaborative planning were emphasised.	4.47	0.70	high	4
9. Students developed systematic and analytical thinking.	4.42	0.77	high	5
10. Lessons reflected real-world contexts.	4.63	0.50	highest	2
Total average	4.51	0.30	highest	

According to Table 5, the strengths are simulations, increased motivation and engagement, and lessons reflect real-world contexts. The weaknesses are that the content was effectively connected to real tasks, and the overall mean score for students' satisfaction was 4.51, indicating a high level of satisfaction. A bar chart is presented in Figure 4. This figure illustrates the mean scores of 19 students' satisfaction with vocational certificate students at Lopburi Technical College for the learning management model that integrates the MIAP model with simulation-based learning, based on ten evaluation items, allowing for a more accessible interpretation of the data.

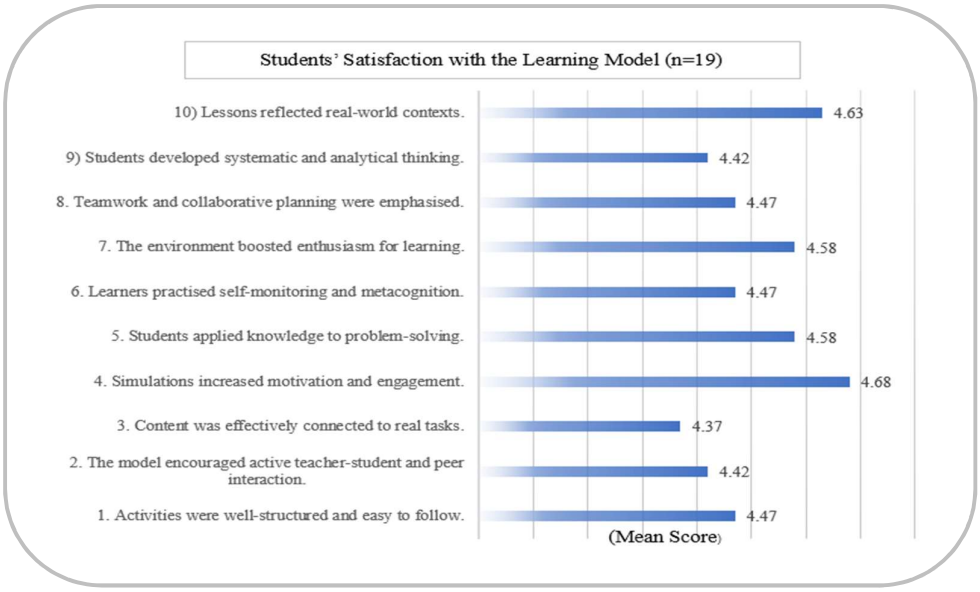

Figure 4: Students' satisfaction with the learning model presented in bar chart format

V. CONCLUSION AND DISCUSSION

This research aimed to develop outdoor electrical installation skills through an instructional model that integrates the MIAP learning model with simulation-based learning (SBL) for third-year vocational certificate students at Lopburi Technical College. The study involved 19 participants and was implemented through activities designed to promote analytical thinking and hands-on practice. The results showed that the developed instructional model was of high quality, which led to students' significantly higher learning achievement after learning through the integrated learning model ($p < .05$) and an average outdoor electrical installation skill score of over 70 percent. Furthermore, learner satisfaction was also rated high, indicating that the model effectively enhanced both vocational skills and practical learning experiences in outdoor electrical installation.

The developed instructional model, which integrates the MIAP learning model with Simulation-Based Learning (SBL), was evaluated by five experts and found to be of high quality ($\bar{x} = 4.34$, SD = 0.37). The model underwent a rigorous validation process by educational experts before implementation. The findings are consistent with Sriudomkij et al. (2020, pp. 381-396), who developed a computer-based instructional model that employed simulations integrated with problem-solving processes, which demonstrated that a well-designed instructional model can significantly enhance learners' knowledge and skill acquisition. Furthermore, the study by Karnna and Prathoomthong (2020, pp. 12-21), who developed an MIAP-based instructional package combined with multimedia computer lessons to improve electrical measuring tool competencies among vocational students, supports these findings. Thus, learning through realistic and practical experiences combined with the structured phases of the MIAP model is deemed suitable for vocational certificate students. Students showed significantly higher academic achievement after learning through the integrated learning model

($t = 12.02$, $p < .05$). This indicates that the combination of the MIAP Model, which focuses on motivation, information, application, and reflection, and SBL, which emphasizes real-life experiences, can effectively enhance students' understanding and ability to apply knowledge. This result is consistent with Poopamonkaipob et al. (2020, pp. 111–118), who found that using MIAP with online lessons on condition design for vocational students significantly improved their academic performance, and Hansena and Jumrusprasert (2024, pp. 26-39) found that using inquiry-based learning together with simulation activities improved critical thinking and problem-solving skills among lower secondary school students. Therefore, integrating the MIAP model with simulation-based experiences is an effective instructional approach that helps improve academic achievement, especially for vocational certificate students. Students who learned through the developed instructional model showed high outdoor electrical installation skills (average score was 3.15 out of 4.00, or 78.82%). The results show that the learning model helped students improve their practical skills. This finding matches Pengsook (2022, pp. 103-114), who found that using simulation-based learning helped students improve their problem-solving skills. Students scored much higher after learning, showing that working in realistic situations helps with understanding and real practice and Raksapakdee and Chaipichit (2022, pp. 46-58), who used direct teaching and peer coaching to teach outdoor electrical installation, reported an average score of 78.41%, with over 80% of students passing the standard. Therefore, hands-on learning combined with simulation-based activities can effectively develop students' practical skills. Students showed a high level of satisfaction with the developed instructional model ($\bar{x} = 4.51$, SD = 0.30) because the learning activities were clear and closely related to real working environments. The model gave students meaningful opportunities to engage with the content, which helped them understand and apply the knowledge effectively. This is consistent with Hutamarn (2022, pp. 32-43) used the MIAP learning model with demonstration kits and simulation worksheets in a course on electric drive and servo systems. His study found that students were highly satisfied with the model. Similarly, Prathoomthong and Karnna (2022, pp. 141-156) developed a lesson using MIAP and game-based learning for teaching basic programmable controllers and found that students had the highest level of satisfaction. Therefore, learning models that promote student participation, provide strong teacher support, and use suitable technologies can effectively increase student satisfaction.

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A DEVELOPMENT OF THE FUNDAMENTAL MATH BOARD GAME FOR ENHANCING THE FOURTH-GRADE THAI STUDENTS' ARITHMETIC ACHIEVEMENT AND MOTIVATION

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ABSTRACT

Nowadays, one effective learning method is board game-based learning, which is particularly appealing to fourth-grade Thai elementary students. This research and development (R&D) study, grounded in the design thinking approach and game-based learning principles, aimed to develop a fundamental math board game on addition, subtraction, multiplication, and division to enhance the arithmetic achievement and motivation of fourth-grade Thai students through the design thinking approach. For this purpose, researchers investigated the effects of a fundamental math board game on the academic achievement and experience of the fourth-grade Thai students. The developed board game, based on the concept of design thinking, was evaluated by three academic experts, who rated its instructional quality as high level ($\bar{x}$ = 4.61, SD = 0.15). Thirty-six fourth-grade students from Thanyasit Silpa School, participating in the second semester of the 2024 academic year, were selected through a Cluster sampling method to learn fundamental mathematics using this board game-based approach. Researchers collected all data, consisting of pretest and post-test achievements and performances, to be analyzed. The results of a dependent t-test comparison indicated that the students' post-test scores ($\bar{x}$ = 16.75, SD = 1.83) were significantly higher than their pretest scores ($\bar{x}$ = 7.11,

SD = 2.14). Additionally, the students expressed high satisfaction with the learning experience ($\bar{x}$ = 4.75, SD = 0.52). These findings confirm that the developed fundamental math board game effectively enhances academic achievement and attracts interest in math learning for fourth-grade Thai students, and suggest that the developed boardgame can serve as on effective pedagogical tool for enhancing arithmetic competency and fostering motivation in elementary mathematics education.

Keywords: Board game, Fundamental mathematics, Design thinking approach, Arithmetic achievement, Learning motivation

I. INTRODUCTION

In today's educational landscape, the mathematics field is an essential subject for the digitally aged elementary students. It is the essential core of STEM (Science, Technology, Engineering, and Mathematics) components, providing the logical framework, problem-solving skills, and analytical tools necessary to understand and apply concepts across science, technology, and engineering. Especially, the arithmetic skill is the essence of fundamental mathematics. It enables precise analysis and communication of ideas, fosters critical thinking, and facilitates the development of solutions to real-world challenges. The Arithmetic is widely acknowledged by educators and researchers as essential across all academic subjects to enhance student performance in the current generation that the one competency of the 21st-century skills refer to the 3R8C framework in Thailand, which includes Reading, wRiting, aRithmetic, Critical thinking, Creativity, Cross-cultural understanding, Collaboration, Communication, Computing, Career and learning, and Compassion skills (Poonputta & Nuangchalerm, 2024, pp. 98-113). Despite, the National council of Thailand has included Arithmetic skill as a needed competency of Thai students in the National Scheme of Education B.E. 2560-2579 (2017-2036) (Office of the Education Council, 2017) and promoted as the future skill of the 21st-century world (Office of the Education Council, 2022), the dilemmas of mathematics education seem the decline of student performances in mathematics over time. PISA Thailand (2020, pp. 1-68) reported that the proportion of Thai students at higher benchmarks decreased dramatically while the proportion of the low performers increased, and half of the students may not attain the international basic level of mathematics because of a too low Mathematics score in the national test (O-NET). Despite the importance, Arithmetic skill which is the fundamental mathematics such as addition, subtraction, multiplication, and division operators for fourth-grade students that lays the groundwork for more complex topics, such as fractions, decimals, and area measurement, many students have found a lack of motivation in elementary school caused by a lack of learning method that can attract the elementary students' interesting. Sappaile (2024, pp. 1-13) reported his gamification method, which incorporated game elements such as points, levels, and challenges, resulting in greater increases in elementary students' interest, engagement, and overall motivation. Meanwhile, Nguyen et al. (2024, pp. 1-12) reported the effectiveness of STEM education using board games for senior high school students in Vietnam, suggesting that teachers should integrate board games into STEM education to enhance student engagement and understanding of STEM concepts. Consistent with the researcher's study results that we studied and surveyed a problem in the mathematics

class of fourth-grade students from Thanyasit Silpa School in Pathum Thani province, and found a low achievement problem, specifically the students' lack of Arithmetic competency, which is a basic fundamental of Mathematics. Almost all respondents were unable to solve problems using basic mathematical operations, such as addition, subtraction, multiplication, and division, and found the traditional lecture method boring.

Lack of motivation in learning, which adversely affects academic achievement, has been the subject of ongoing research and experimentation by teachers, psychologists, and educational scholars. Various concepts and methods have been employed to address this issue. A review of the relevant literature highlights a learner-centered approach grounded in constructivist principles, conceptualizing the learning process as primarily driven by learners' motivation and enthusiasm. According to this approach, teachers should promote peers' interaction in the classroom within the social context, provide opportunities for practice, facilitate problem-solving of real-world issues, and respond to genuine questions to meet learners' authentic needs (Akpan & Beard, 2016 pp. 392-398; Zajda, 2021 pp. 35-50). Especially among Thai primary school students, numerous research studies support teachers in transforming traditional lecture-based instruction by incorporating active learning through various classroom activities. Such approaches aim to promote a student-centered learning process that enhances student satisfaction and effectively increases academic achievement. Board gaming is a popular activity that several researchers have specifically developed to effectively enhance achievement across various subjects while increasing students' satisfaction more than traditional lecture methods (Punkajab et al, 2023, pp. 141-155; Supandhi et al, 2022, pp. 494-499; Wongchai & Sawangmek, 2023, pp. 49-63).

Researchers developed a board game through the design thinking approach to gain a deep understanding of students' needs, resulting in creative and valuable games that reduce the risk of unreceived products and create opportunities for students to co-develop rules through systematic experimentation and refinement. The design thinking approach is generally defined by many designers as an analytic and creative process that engages a person in opportunities to experiment, create, and prototype models, gather feedback, and redesign through five processes, including emphasize, define, ideate, prototype, and test processes (Razzouk & Shute, 2012, pp. 330-348). The suitability level evaluation form was conducted by researchers under the guidance of their advisor to assess the quality of a prototype using a five-level Likert scale questionnaire, as evaluated by three academic experts. During the experimental period, researchers employed a pretest-posttest design to compare academic achievements using a t-test dependent statistics analysis before and after the intervention. Researchers collected Satisfaction data using a five-level Likert scale questionnaire after the intervention.

This R&D research aims to develop a fundamental math board game using the design thinking approach and to evaluate its impact on fourth-grade Thai students' arithmetic achievement and learning motivation, including its impact on mathematics academic achievement, and the satisfaction data of fourth-grade participants from Thanyasit Silpa School in Pathum Thani province, who learnt the mathematics on addition, subtraction, multiplication, and division using a fundamental math board game that developed by the researcher.

II. LITERATURE REVIEW

The rapid technological, industrial, and social changes in this digital era have led to a shift in global education policies, focusing on STEM: Science, Technology, Engineering, and Mathematics, for widespread research in this decade (Maass et al., 2019, pp. 869–884). Despite mathematics being the prior component of STEM, the role of mathematics in STEM classroom research is still less than that of others. Just & Siller (2022, p. 629) systematically reviewed over 1,900 articles from three popular publication databases, including WOS, ERIC, and EBSCO, and found that only fourteen articles studied the role of mathematics in the secondary classroom. Meanwhile, some educators discussed the role of mathematics in STEM education, including arithmetic competence, which is considered a fundamental mathematics skill that all new generation students need to acquire in order to be successful in the near future. Despite, different vague definitions of 21st-century skills were little vary, almost its was divided by the Partnership for 21st-century Skills (2009, pp. 1-9) into four categories including 1) basic subjects, 2) learning and innovation skills, 3) information, media and technology skills, and 4) life and career skills (Partnership for 21st-century Skills, 2009, pp.1-9; Bircan & Çalışıcı, 2022, pp. 87-119). In Thailand, the 3R8C framework of 21st-century skills consists of reading, writing, arithmetic, critical thinking, creativity, cross-cultural understanding, collaboration, communication, computing, career and learning, and compassion skills, which were wildly acknowledged (Panich, 2012, pp. 1-21; Poonputta & Nuangchalerm, 2024, pp. 98-113). Arithmetic competence directly involves the fundamental mathematics, especially the basic operations, including addition, subtraction, multiplication, and division. Although the Office of the Education Council (2017) promoted arithmetic as a needed future skill in the 20-year National Scheme of Education, PISA and TIMSS reported the critical dilemmas of mathematics education in Thailand, which showed that Thai students had too low mathematics achievement in the national and international tests (PISA Thailand, 2020, pp. 1-68). It is undeniable that the lack of basic mathematics skills at the elementary school level causes many secondary students to encounter problems and obstacles in learning mathematics at higher levels, including mathematical applications across science, technology, and engineering fields. The causal factors include that primary students did not realize the importance of basic skills and knowledge of mathematics that are crucial for future applications at higher levels, and they often think that mathematics problems are too complicated and tedious. At the same time, traditional teaching methods did not motivate them enough. What approaches can solve this dilemma, starting from elementary school mathematics? Board game-based learning has been mentioned as an effective tool for implementing STEM education, with outcomes including cognitive achievements and motivation, especially in primary students (Cardinot et al., 2022; Vita-Barrull et al., 2023; Hashim et al., 2024; Nguyen et al., 2024).

Researchers selected the design thinking approach, which includes the processes of emphasize, define, ideate, prototype, and test, to design and develop a board game's prototype in this study. Razzouk & Shute (2012, pp. 330-348) identified the user-centered features and characteristics of the design thinking approach that are suitable for determining the thinking process of creating a mathematics board game. This approach engaged all stakeholders, including mathematics teachers and fourth-grade students, to explore overall perspectives on needs and expectations through a survey method. Nagai & Taura (2017, pp. 115–133) agreed

and found that the design thinking approach encourages creative exploration. Moreover, prior research highlights persistent deficiencies in Thai students' arithmetic skills, the pedagogical value of learner-centered constructivist environments, and the proven benefits of board game-based learning in enhancing engagement and cognitive performance. These converging insights underscore the necessity of developing a design thinking-driven board game tailored to fourth-grade learners' needs. Therefore, in this study, researchers aimed to develop a suitable fundamental math board game for addition, subtraction, multiplication, and division to enhance the arithmetic achievement and motivation of fourth-grade Thai students through the design thinking approach.

III. RESEARCH METHODOLOGY

This R &D research aimed to develop a fundamental math board game on Addition, Subtraction, Multiplication, and Division for the fourth-grade Thai students through the design thinking approach, as five processes as follows: 1) Emphasize, 2) Define, 3) Ideate, 4) Prototype, and 5) Test.

In the Emphasize process, the beginning of design stage, researchers examined all theories and concepts related to addition, subtraction, multiplication, and division in mathematics subjects in conjunction with the Basic Education Core Curriculum in 2008, revised in 2017, for fourth-grade Thai elementary students (Office of the Education Council, 2017, pp.56-59). Researchers surveyed and interviewed 30 fourth-grade elementary students from Thanyasit Silpa School to identify their mathematical problems using a cluster sampling method. The results showed that they lacked interest and achievement in addition, subtraction, multiplication, and division in mathematics subjects, especially in the division proposition. Therefore, researchers and teachers focused on developing the mathematical board game to facilitate learning and solve this problem. Researchers analyzed and considered the mechanisms and systems of several educational and mathematical board games, including Game Math 24, UNO, and Head Full of Numbers. All possible ideas were discussed with the mathematics teacher, academic experts, and researchers to draft the characteristics of a board game that would appropriately target the fourth-grade Thai students.

In the Define process, two dimensions, including 1) teachers' instruction and 2) students' perception, were defined by researchers and advisors. The results of the survey and observation were as follows: 1) The Instruction of the fourth-grade mathematics: The main problem was the condensed instruction and limited time period, which made it difficult for fourth-grade students to keep up and fully understand the content in the classroom. The students' attention factor is the most important one that causes many students to become bored with traditional lecture activities. Moreover, we found that the math classroom in the afternoon clusters requires an active learning strategy to stimulate the young fourth-grade Thai students more effectively than the morning clusters, which are often fatigued. 2) Students' perception: The findings showed that the fourth-grade samples mostly lacked the division's performance (75%). Meanwhile, 15% of them also demonstrated a lack of proficiency in multiplication. Many students did not pay attention and intend to learn and practice the addition and subtraction operations from the beginning. Therefore, they cannot understand and lack the advanced and complex content, such as multiplication and division.

In these Emphasize and Define processes of designing stage, all intensive data collection through qualitative methods to achieve profound elementary students' insight, where the collected data is synthesized and analyzed to arrive at a definitive and actionable problem articulation.

In the development stage which started with the Ideate process, researchers presented a variety of storyboards and scenarios to academic experts and advisors for advice. Finally, the designed characteristics are illustrated in Table 1.

Table 1: The characteristics of a math board game for the fourth-grade Thai students.

	Characteristics
Type of game:	A collaborative game for two to six physical players to play for around forty minutes per game.
Physical tools:	One set of a math board game, including: 1) two big bingo boards (8x8), 2) players' coins (six colors), 3) a deck of sixty-four proposition cards, 4) a deck of extra cards (thirty punishment cards and seven command cards), and 5) six mini-whiteboards.
Theme:	Role-play with the Halloween theme
Levels:	1. Level 1: Addition, Subtraction, and Multiplication practices 2. Level 2: Division practices
Rules:	1. Player shuffle sixty-four cards in the Q1 deck of level 1. 2. Player shuffle thirty punishment and seven extra cards in the Punishment Deck. 3. All players must play level 1 with the level 1's bingo board and Q1 deck before changing to level 2's bingo board and Q2 deck instead when level 1 finishes.
	4. In the first round, all players start with five cards in hand. Everybody considers collecting two preferred cards in their hands and sending the remaining three cards to the next player, until the first player receives the final three cards from the last player, at which point the game is ready. 5. Whoever can put completely his/her four of their coins in a line on a big bingo board will be the winner, or the game will be over when nobody wins.
Mechanism:	1. Level 1, when all players have five initial cards in hand, the game is ready to play. 2. The first player selects and opens his/her one in-hand card to calculate in one minute and speak the answer on time. If his/her answer is correct, he/she can put his/her colour coin on a matched result number's position of the bingo board and pick one new card from the top of the Q1 deck to finish their turn. 3. The second player and following players play the same as the first player until the winner can make a bingo with his/her four coins in a line of any direction on a big bingo board, or no winner if no cards are in the proposition deck. 4. In case any player's answer is incorrect, they must draw a punishment card from the punishment deck and take a rap before finishing his/her turn. However, if they draw an extra card from a punishment deck instead, they can select the special act followed by the card's condition. 5. If someone wins the level 1 bingo board with their four coins in a line, all players will restart the level 2 game with the Q2 card deck and level 2 bingo board.
Hints:	* Allow players to use a whiteboard to calculate their propositions while playing.

In the Prototype process, all suggestions and comments were considered to revise the prototype's mechanism and rules before the researchers developed the prototype and instructions. A set of the math board game and card examples is illustrated in Figure 1. During the development stage of both the Ideate and Prototype processes, researchers employed techniques for conceptualization and idea generation, aiming for maximum creativity and quantity. The most promising concepts were then materialized in the Prototype process, which

is characterized by rapid construction of testable artifacts before committing significant resources.

Figure 1: A set of the math board game and card examples

In the Test process, which encompassed both Validation and Assessment of this solution, these processes inherently covered actions including checking the functionality and usability of the prototype through expert and user trials, ensuring the solution is robust and intuitive, and refining the solution's overall success in addressing the original defined problem and goal. The prototype math board game was qualified and evaluated as a research instrument by three academic experts, yielding an average rating of the highest quality level ($\bar{x}$ = 4.60, SD = 0.57). Researchers considered all comments and recommendations from stakeholders to improve the released prototype.

Researchers developed and validated all research instruments as follows: 1) a set of math board game prototypes, 2) a suitability assessment questionnaire, 3) achievement tests, and 4) a satisfaction questionnaire. Therefore, after a final prototype was done, researchers conducted a suitability assessment form and presented it to the advisor for verification, along with suggestions and recommendations for improvement. Three academic experts specializing in teaching, measurement, and evaluation assessed the content validity using the IOC (Item-Objective Congruence) index rating. Researchers collected all quality feedback to improve the form. Meanwhile, researchers developed eighty test items to serve as a bank of items for assessing pretest and post-test achievements.

Three academic experts in mathematics assessed the content validity of all items using the IOC index rating, thirty (30) items shown an IOC index from 0.67 to 1.00, and researchers selected qualified items to create an achievement test for a thirty-trial group (30) of fifth-grade elementary students who had passed the mathematics course in the previous semester. Researchers analyzed all qualification values of the test, including a difficulty (p) value (0.2-0.8), a discrimination power (r) value (0.2-0.8), and the reliability of the test form, as determined by the KR-20 formula (>0.8). The results shown a difficulty value (p) ranging from 0.404 to 0.629 and discrimination power (r) ranging from 0.361 to 0.750. The reliability, calculated using the KR-20 formula, was found to be high at 0.820.

Finally, at the end of this step, a satisfaction questionnaire was developed and qualified through three academic experts. All satisfaction questions were assessed for content validity by the IOC index rating of three experts. The fifty-five (55) satisfaction assessment items also showed an IOC index from 0.67 to 1.00.

The population of this study consisted of fourth-grade elementary students from Thanyasit Silpa School in Prathum Thani Province, Thailand, who were enrolled in the second academic semester of 2024, totalling two-hundred and sixty-three (263) students across seven sections (aged between 9 and 11 years old). One section (section 4/6) included thirty-six (36) samples that participated in the examination by the clustering sampling method as the representative group of six homogenous sections. Thanyasit Silpa School and the mathematics teacher granted permission to collect research data. For ethical reasons in human research, all participants under eighteen years old and their parents were informed of the experiment and voluntarily consented before the intervention.

In the Oriental session, all participants took the pretest examination before the experiment began. During the game session, the teacher divided all the students into six groups. All groups studied the math board game mechanics and rules through animation media and an instruction manual for fifteen (15) minutes before playing. Meanwhile, all participants played a math board game for two (2) hours, and all qualitative and quantitative experience data were observed and collected by notes. When all games finished, all participations took the post-test examination, and finally researchers interviewed all participants and requested them to reflect on their attitudes through the satisfaction questionnaire. Researchers collected all the data for analysis. Some experimental atmospheres are illustrated in Figure 2.

Figure 2: Experimental atmospheres

IV. RESULTS

In this section, all results show the suitability level of a fundamental math board game on addition, subtraction, multiplication, and division for the fourth-grade Thai students through the design thinking approach, and the effectiveness on academic achievement and satisfaction of the fourth-grade Thai students is as follows;

The suitability level of a fundamental math board game, covering addition, subtraction, multiplication, and division, for fourth-grade Thai students was evaluated by three academic experts for its quality and suitability in five aspects, as shown in Table 2.

Table 2: Suitability level of a fundamental math board game (n=3).

Board game's aspects	$\bar{x}$	SD	Suitability Level
1. Mathematical context	4.58	0.51	Highest
2. Board game design	4.70	0.47	Highest
3. System and mechanism	4.67	0.48	Highest
4. Problem-solving skills	4.38	0.74	High
5. Effectiveness & retention	4.62	0.59	Highest
Total	**4.60**	**0.57**	**Highest**

In Table 2, the overall suitability of the board game was at the highest level ($\bar{x}$ = 4.60, SD = 0.57). Four aspects met the highest level, namely the board game design ($\bar{x}$ = 4.70, SD = 0.47), system and mechanism ($\bar{x}$ = 4.67, SD = 0.48), effectiveness and retention ($\bar{x}$ = 4.62, SD = 0.59), and mathematics context ($\bar{x}$ = 4.58, SD = 0.51), respectively. Only the problem-solving skills aspect was high level ($\bar{x}$ = 4.38, SD = 0.74), with three sub-aspects being high level, including collaboration with peers ($\bar{x}$ = 4.00, SD = 1.00), problem-solving skills ($\bar{x}$ = 3.67, SD = 0.58), and daily-life application ($\bar{x}$ =3.67, SD = 0.58).

The effectiveness of a fundamental math board game in enhancing academic achievement in addition, subtraction, multiplication, and division for fourth-grade Thai students is demonstrated through a dependent t-test comparison analysis, as shown in Table 3. Prior to conducting a dependent t-test the statistical assumptions were checked. The academic achievement was measured on a continuous scale and the observations were considered independent across pairs. The key assumption of normality by Shapiro-Wilk was checked with no outliers. Therefore, the dependent t-test assumptions were considered met.

Table 3: The dependent t-test comparison analysis (n=36).

Academic achievement	n	$\bar{x}$	SD	T
Pretest	36	7.11	2.14	-23.61**
Post-test	36	16.75	1.83	

This result shows that fourth-grade Thai students improved their academic achievement in fundamental mathematics, specifically in addition, subtraction, multiplication, and division, as indicated by the average Post-test score ($\bar{x}$ = 16.75, SD = 1.83), which is significantly higher than the average Pretest score ($\bar{x}$ = 7.11, SD = 2.14). This quantitative finding is strongly supported by the qualitative observations noted during the intervention. The joyful atmosphere and collaborative nature of the game fostered heightened peer interactions, specifically through the activation of cooperative learning mechanisms and co-construction of knowledge. The observed peer assistance, where some students helped their peers solve more challenging propositions (especially division problems at Level 2) by providing hints, serves as a direct manifestation of Vygotsky's Zone of Proximal Development (ZPD). This peer scaffolding is crucial, as it allowed struggling students to master tasks that were initially beyond their independent capability, thereby translating positive social interaction into concrete cognitive gains and ultimately, improved academic achievement.

The satisfaction of the fourth-grade Thai students who learnt through a fundamental math board game on addition, subtraction, multiplication, and division, as shown in Table 4.

Table 4: Satisfaction level of a fundamental math board game (n=36).

Board game's aspects	$\bar{x}$	SD	Satisfaction Level
1. Board game design	4.74	0.53	Highest
2. Mathematical content	4.76	0.51	Highest
3. Board game-based learning	4.72	0.54	Highest
4. Mechanism	4.79	0.44	Highest
5. Outcomes	4.76	0.51	Highest
Total	4.75	0.52	Highest

This table shows that the satisfaction of fourth-grade Thai students achieved the highest overall score on a fundamental math board game ($\bar{x}$ = 4.75, SD = 0.52). All of sub-aspects was highest level including of the mechanism ($\bar{x}$ = 4.79, SD = 0.44), mathematical content ($\bar{x}$ = 4.76, SD = 0.51), outcomes ($\bar{x}$ = 4.76, SD = 0.51), board game's design ($\bar{x}$ = 4.74, SD = 0.53), and board game-based learning ($\bar{x}$ = 4.72, SD = 0.54), respectively. Board game-based learning fostered higher levels of student satisfaction, which resulted in a significantly greater increase in fourth-grade students' intrinsic motivation, willingness, and effort compared to traditional exercises. This effect was qualitatively substantiated by observations that participants calculated mathematical propositions more easily and with superior focus during the game intervention than during homework or assignments.

V. CONCLUSION AND DISCUSSION

The design thinking approach including emphasize, define, ideate, prototype, and test processes, that focused on understanding the needs of fourth-grade Thai students allowed developers gain insights into the actual needs, preferences, and challenges faced by participants, resulting in a fundamental math board game that were more responsive to participants and the highest suitability level ($\bar{x}$ = 4.60, SD = 0.57) from evaluators in overall aspects including board game design, system and mechanism, effectiveness and retention, mathematical context, and problem-solving skills aspects. When researchers experimented the effectiveness of a fundamental math board game with thirty-six fourth-grade Thai participants, the results showed that all participants developed their academic achievement in fundamental mathematics on addition, subtraction, multiplication, and division as indicated by the average post-test score ($\bar{x}$ = 16.75, SD = 1.83), which is significantly higher than the average pretest score ($\bar{x}$ = 7.11, SD = 2.14). Moreover, this fundamental math board game achieved the highest satisfaction level ($\bar{x}$ = 4.75, SD = 0.52) in all aspects, including its mechanism, mathematical content, outcomes, design, and learning through board games.

The user-centered approach of design thinking processes helped researchers to develop a suitable fundamental math board game for the needs of fourth-grade Thai students, according to Micheli et al. (2018, pp. 124-148), who explored the perspectives of research educators who identified perspectives of scholars writing about design thinking, and provided detailed recommendations for relevant topics warranting further study in order to advance theoretical understanding of design thinking and test its applications. The results confirm the success of

using design thinking approach to develop a fundamental math board game, achieving high suitability and satisfaction, and leading to a significant improvement in academic achievement. This effect is explained by the process's ability to precisely meet the fourth-grade students' psychological and intellectual needs, thus effectively mediating the necessary intrinsic motivation and learning effort for cognitive mastery. Through the examination of complex problems and creative brainstorming, designers developed new ideas for game mechanics, rules, and content to create unique and engaging experiences for participants. The effectiveness of a developed fundamental math board game in the mathematical academic achievement increasing significantly after the intervention, confirmed that fourth-grade Thai students developing their learning process while playing a fundamental math board game, in line with Noda et al. (2019, pp. 1-21) examined the effectiveness of board games through the systematic review method of seventy-one studies, that board games have positive effects on three dimensions, including educational knowledge, cognitive functions, and others. In Thailand, many educators developed the board game-based learning to promote Thai students' achievements including Punkajab et al. (2023, pp. 141-155) developed the card game to promote reading skills of upper elementary school students who lacked of vocabulary scores, and the result showed card game would be increased efficiency of reading skills to remember Thai vocabulary, Supandhi et al. (2022, pp. 494-499) developed a board game as supplementary material for students to learning English grammar very well and fun, they shown the board game model was proper to improve grammar ability of the senior high school students in learning English grammar, or Wongchai and Sawangmek (2023, pp. 49-63) developed the guidelines for adaptive learning management with board games for enhancing learning progress in science of the fourth-grade students in Phrae Province, and reported the students have made more progress in learning science after learning adaptive learning management with board games. Additionally, board game-based learning would enhance the interpersonal interactions and learning outcomes of participants, which would attract youth students. The joyful atmosphere made them satisfied with practicing and learning, as evidenced by the results, which found that a fundamental math board game met the highest level of satisfaction ($\bar{x}$ = 4.75, SD = 0.52) among the fourth-grade Thai participants. In line with Christian and Prasida (2018, pp. 78-88), who employed a mixed-methods study to develop a board game as learning media for waste sorting awareness among Indonesian fourth-grade elementary students, their study revealed that nearly all fourth-grade students showed greater interest in learning through a board game. So, the game-based teaching is the one of the most effective methods that provides a stress-free environment for children and suits for increasing students' interest in learning, especially the educational board games (Barekat, 2023, pp. 68-75), in line with Nguyen et al. (2024, pp. 1-12) who found the board game-based learning was fit in the delivery of STEM education to increase students' motivation and achievement. Therefore, this research's findings confirm that a developed fundamental math board game, created through the design thinking approach, effectively enhances academic achievement and attracts interest in math learning among fourth-grade Thai students. Nevertheless, several contextual and methodological limitations of this study must be acknowledged. Specifically, the limited sample size (n=36) and the brief intervention duration (2 hrs.) pose constraints. These factors may restrict the generalizability of the findings, suggesting that the results should be interpreted

with caution regarding their direct application to larger, diverse elementary student populations or long-term academic improvement. Future research should address these limitations by utilizing a larger, more diverse sample population and extending the intervention duration to several weeks or a full academic semester. This will allow for a more robust assessment of the boardgame's long-term efficacy in terms of knowledge retention and the sustainability of increased intrinsic motivation. Beyond the successful creation of this board game, the Design Thinking approach offers a high-potential framework for driving comprehensive instructional innovation across Thai elementary education. Its application represents an investment in a creative, iterative process that guarantees resulting innovations will exhibit high suitability, effectively foster satisfaction, and ultimately lead to sustainable improvements in academic achievement.

SUGGESTION

During the intervention, researchers observed and noted the effects of various 21st-century skills in fourth-grade Thai participants as they attempted to solve math problems through a board game, including critical thinking, problem-solving, and collaboration skills, while assessing situations, planning strategies, and making rational decisions. Board game-based learning can enhance more essential skills that encourage students to think outside the box, find solutions, communicate, and negotiate with peers to win the game. In the future, researchers may extend these observations to study the effectiveness of board game-based learning in developing related 21st-century skills in elementary Thai students.

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EXPLORING THE IMPACT OF STRESS ON TURNOVER INTENTION AMONG CHINESE UNIVERSITY LECTURERS: MEDIATING EFFECTS OF BURNOUT, WORK-FAMILY CONFLICT, AND SATISFACTION

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ABSTRACT

Over recent years, there has been a noticeable increase in the attrition rate among university lecturers in China. Numerous reasons, including high work stress, low salaries, and a rigorous performance appraisal system, have led to this phenomenon. The study aims to investigate the impact of stress on the turnover intention of Chinese university lecturers specifically examining the mediating effects of burnout, work-family conflict, and satisfaction. The researcher used a questionnaire to collect data and surveyed a total of 387 university lecturers from eight universities in China. Using SmartPLS 4.0 software, the researcher tested the hypotheses and analysed the mediating effects through partial least squares structural equation modelling (PLS-SEM). The study that all the constructs, except work-family conflict, were able to impact lecturers' turnover intention significantly. Furthermore, stress was found to indirectly affect lecturers' turnover intention through both burnout and satisfaction. This study can provide insights for higher education administrators and policymakers.

Keywords: Stress, Turnover intention, Burnout, Work-family conflict, Satisfaction, PLS-SEM, Mediation

I. INTRODUCTION

In the current era of the global knowledge economy, it is essential for countries to enhance their core competitiveness by investing in the advancement of higher education (Altbach, 2013, pp. 316-330). The Ministry of Education of the People's Republic of China (MOE of PRC) has launched a higher education development program to develop selected outstanding universities into world-class leading universities, and this decision also raises the requirements for university lecturers. MOE of PRC has implemented reforms to the personnel policy and lecturers' responsibility in higher education to enhance the quality alongside the expansion of higher education (Yin & Ke, 2017, pp. 1145-1158). The Implementation Program for Deepening Comprehensive Reforms in the Field of Education, released by MOE of PRC in 2014, requires university lecturers to take on heavier teaching and research tasks, further exacerbating the conflict between teaching and research among Chinese university lecturers (Lai et al., 2014, pp. 966-979). Therefore, establishing a modern Chinese higher education system brings new challenges to Chinese university lecturers (Han et al., 2021 pp. 247-262).

Higher education lecturers often confront numerous challenges that significantly impact their professional development and effectiveness in the academic setting, especially in China. Since the 1990s, Chinese universities have introduced the U.S. tenure system, referring to a teacher employment system in which universities grant tenure to eligible faculty members, guaranteeing their academic freedom and other rights so that faculty members are no longer restricted by employment contracts (Herbert & Tienari, 2013, pp. 157-173; Wang & Wang, 2024, pp. 1-11). However, tenure is currently only practiced in several of China's leading universities, resulting in a situation where implementation contracts coexist with tenure, which creates a problem where academic promotion is more difficult in China compared to other countries (Wang & Jones, 2021, pp. 49-66; Yang et al., 2024, pp. 476-492). Chinese universities implement a rigorous evaluation system encompassing both academic and teaching assessments. To improve schools' academic rankings and obtain financial support from the government, Chinese universities have adopted performance evaluation and incentive systems to compel university faculty to produce more academic outputs (Tian et al., 2016, pp. 9-17).

Driven by Chinese policies oriented towards teaching and academic output, university lecturers are assigned more teaching and research tasks by their institution, leading to a notable increase in stress levels (Tian & Lu, 2017, pp. 957-974). Regarding teaching work, the requirements for reforms and innovations from university and government policy have caused university lecturers to face increased teaching workloads and adaptation to new teaching strategies and technologies (Han et al., 2021, pp. 247-262). Regarding research work, insufficient research funding given by the university or government is a pain point for university lecturers, who generally feel that there needs to be more financial support for their research activities (Du et al., 2010, pp. 430-449). Regarding career advancement, many Chinese universities practice an "Up-or-out" system, with fierce competition for both lecturer and professor positions, and the limited number of positions makes it so that many university lecturers often have to wait until the retirement of older lecturers before they can be promoted (Lai et al., 2016, pp. 516-530). New university lecturers face the expectation of meeting

specific publication requirements within a designated timeframe in reputable international indexed journals, which can potentially yield enhanced salary and promotion prospects, while failing to meet these expectations may result in job termination upon contract expiration (Qiu, 2010, p. 142; Tian et al., 2016, pp. 9-17; Wang et al., 2023, pp. 2066-2079). As a result of high levels of stress and burnout, Chinese university lecturers have a high turnover rate, resulting in severe educational problems, including low retention and a shortage of university lecturers (Wang et al., 2023, pp. 2066-2079). Overemphasizing competition, performance, and a ruthless phaseout system has also led university lecturers to be more concerned with short-term research outputs and the number of journal publications, neglecting the quality and value of research and sacrificing lecturers' personal development and academic freedom (Henkel, 2005, pp.155-176; Yang et al., 2007, pp. 575-592). As a result, some Chinese university lecturers have a high turnover intention, which poses a significant challenge to developing higher education (Zhang et al., 2022, pp. 1-18).

The primary objective of this study is to examine the impact of stress on turnover intention among Chinese university lecturers. In addition, the study aims to investigate the mediating roles of burnout, work–family conflict, and job satisfaction in the relationship between stress and turnover intention, in order to clarify the underlying psychological and organizational mechanisms. By comparing the relative explanatory power of these mediators, the study seeks to identify the key factors through which stress influences lecturers' intentions to leave, thereby providing empirical evidence to inform strategies for improving faculty well-being and retention in higher education.

II. LITERATURE REVIEW

Stress has long been recognized as a foundational construct in organizational and educational psychology, referring to the emotional and physiological responses individuals experience when external demands exceed their coping capacities (Lazarus & DeLongis, 1983, pp. 245–254; Lazarus & Folkman, 1984, p. 105). In academic settings, teacher stress commonly manifests as anxiety, frustration, and emotional strain resulting from work-related pressures (Kyriacou, 1987, pp. 146–152). For Chinese university lecturers, empirical studies have identified insufficient institutional support, heavy teaching workloads, escalating research expectations, and shifts in evaluation mechanisms as key sources of stress (Lai et al., 2016, pp. 516–530; Tian & Lu, 2017, pp. 957–974; Wei & Ye, 2022, pp. 1–16). Globally, intensifying competition and rapid reforms within higher education have contributed to rising stress levels among faculty (Tytherleigh et al., 2005, pp. 41–61; Watts & Robertson, 2011, pp. 33–50), which have been linked to mental-health decline, impaired performance, and increased turnover intentions (Gillespie et al., 2001, pp. 53–72; Salvagioni et al., 2017, pp. 1–18; Zhang et al., 2019, pp. 414–435). Closely related to occupational stress is work-family conflict, a form of inter-role tension arising when work and family responsibilities become mutually incompatible. Greenhaus and Beutell's (1985, pp. 267–278) tripartite model illustrates time-based, strain-based, and behavior-based forms of conflict, all of which are prevalent among Chinese faculty as demanding work schedules increasingly intrude on personal life (Rajendran et al., 2020, pp. 1–24). This conflict has been associated with reduced job satisfaction,

heightened turnover intention, and diminished well-being (Allen et al., 2000, pp. 278–308; Cinamon & Rich, 2005, pp. 365–378). Burnout, conceptualized as a chronic and maladaptive response to prolonged stress, further compounds these challenges. Defined by emotional exhaustion, depersonalization, and diminished personal accomplishment (Freudenberger, 1989, pp. 1–10; Maslach et al., 2001, pp. 397–422), burnout is frequently explained through the Job Demands–Resources (JD-R) framework, which posits that excessive job demands combined with inadequate resources accelerate emotional strain (Schaufeli et al., 2001, pp. 565–582; Saloviita & Pakarinen, 2021, pp. 103–221; Wang et al., 2020, pp. 1314–1328). Chinese university lecturers, operating within increasingly competitive academic environments, are particularly vulnerable to burnout due to sustained workloads and limited support (Zhong et al., 2009, pp. 1248–1254). Job satisfaction is defined as individuals' evaluative judgments of their work conditions (Weiss, 2002, pp. 173–194), represents another core variable shaping faculty well-being and organizational behavior. Influenced by factors such as work environment, autonomy, compensation, and advancement opportunities (Coomber & Barriball, 2007, pp. 297–314), job satisfaction has been linked to improved performance, organizational commitment, and professional engagement (Aziri, 2011, pp. 77–80; Bogler, 2001, pp. 662–683; Meyer et al., 2002, pp. 20–52).

Grounded in stress theory and the Job Demands–Resources (JD-R) model, this study examines the impact of stress on turnover intention among Chinese university lecturers while analyzing the mediating roles of burnout, work-family conflict, and job satisfaction. The conceptual framework, presented in Figure 1 below. Specifically, the study proposes a series of hypotheses to capture these relationships: H1, stress has a significant impact on turnover intention; H1a, stress significantly influences work-family conflict; H1b, stress significantly influences burnout; H1c, stress significantly influences job satisfaction. Additionally, H2, work-family conflict significantly affects turnover intention; H2a, work-family conflict significantly affects burnout; H2b, work-family conflict significantly affects job satisfaction. Further, H3, burnout significantly affects turnover intention; H3a, burnout significantly affects job satisfaction. Finally, H4, job satisfaction significantly affects turnover intention. Together, these hypotheses enable a comprehensive examination of the mechanisms through which stress exerts its influence on turnover intention, providing a theoretically grounded and empirically testable model for understanding faculty well-being and retention in Chinese higher education.

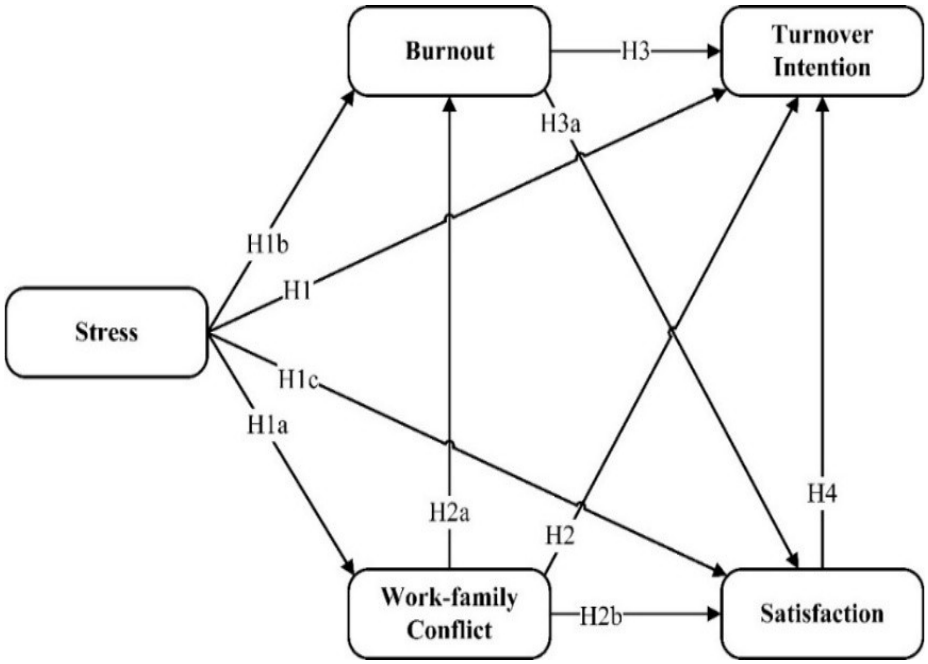

Figure 1: Conceptual framework of this study

III. RESEARCH METHODOLOGY

Participants

The participants in the present study consisted of Chinese full-time lecturers in 8 designated respective universities from 4 big provinces of China, including Henan, Shandong, Hunan, Zhejiang province. The total population reached 18,905, while the sample of participants was 387 based on Krejcie & Morgan's (1970) sample method.

The study used a questionnaire as the primary research instrument, the researcher developed the web-based questionnaire using the WJX platform and then distributed it using QR codes on WeChat, QQ, and other social media platforms. Through the snowball sampling, the researcher asked participants to aid in distributing the questionnaire to their colleagues or acquaintances after completing their own questionnaire responses.

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Research instrument

The questionnaire was the data collection instrument for this study, and it included three parts: screening questions, demographic questions, and scale items. The screening questions were primarily used to assist with judgmental sampling and consisted of two questions that asked the participant about the university they worked at and their job responsibilities. Only lecturers employed at the 10 designated universities, with responsibilities in teaching and research, were allowed to continue with the following answers. In the second part, the researcher obtained demographic information from the participants, including their gender, educational background, academic title, and teaching experience.

The scale items included five major constructs (stress, burnout, work-family conflict, satisfaction, and turnover intention) adopted by comparable research studies. All scale items were measured using a five-point Likert scale, where participants had to choose a number ranging from 1 (strongly disagree) to 5 (strongly agree).

1) Stress: The scale for stress was adapted from Han et al. (2021), namely Sources of Faculty Stress (SFS), which was originally developed by Leung et al. (2000, pp. 121-138). 2) Burnout: The scale used to measure burnout in this study was the Maslach Burnout Inventory Educators Survey (MBIES) designed by Maslach and Jackson (1981, pp. 99-113). 3)Work-Family Conflict: The Work-Family Conflict Scale was derived from the questionnaire created by Netemeyer et al. (1996, pp. 400-410), including ten items. 4) Satisfaction: The satisfaction scale utilized in this study was derived from the Teaching Satisfaction Scale (TSS) developed by Ho and Au (2006, pp. 172-185), consisting of five items. 5) Turnover Intentions: The Turnover Intentions Scale was derived from the four-item questionnaire that Kelloway et al. (1999, pp. 337-346) developed. The Cronbach's alpha values of these scales are all over 0.86, which exceeds the threshold of 0.7, indicating that the scale contains both internal consistency and reliability.

Data analysis

Since the researcher set the questionnaire to be submitted only if all items were answered, there were no missing values in the data of this study. Descriptive statistics were used for determine the levels of lecturer' stress, burnout, work-family conflict, satisfaction, and turnover intention at these Chinese universities. The Partial Least Squares Structural Equation Modeling (PLS-SEM) is particularly suitable for predictive modeling, where the primary purpose is to make forecasts or predictions rather than hypothesis testing (Sarstedt et al., 2021, pp. 587-632). Insufficient studies have confirmed the causal relationships between the constructs in this study, and therefore, the model tends to be more of a predictive model. PLS-SEM is better for predicting model outputs than covariance-based structural equation modeling (CB_SEM) when the model is in high order (Dash & Paul, 2021, pp. 1-11). Stress and burnout, composed of seven and three subconstructs, are higher-order constructs with complexity. PLS-SEM is deemed more appropriate for evaluating the model in this research since it offers more accuracy and convenience. Therefore, SPSS 24 was utilized for descriptive analysis of demographic data and scale items, while SmartPLS 4.0 was utilized for reliability testing, hypothesis testing, and mediation effects analysis.

IV. RESULTS

Descriptive statistics analysis

Table 1 summarizes the descriptive statistics for stress, burnout, work–family conflict, satisfaction, and turnover intention among Chinese university lecturers (N = 387). Overall, respondents reported moderate to high levels across the measured constructs. Stress was reported at a moderate level (M = 3.45, SD = 0.790), indicating noticeable but not extreme work pressure. In contrast, burnout (M = 3.60, SD = 0.776) and work–family conflict (M = 3.52, SD = 0.808) both reached high levels, suggesting substantial emotional exhaustion and role interference among participants. Job satisfaction remained moderate (M = 3.46, SD = 0.699), reflecting neither strong dissatisfaction nor high fulfillment. Turnover intention also fell within the moderate range (M = 3.40, SD = 0.829), indicating a nontrivial inclination to consider leaving the profession. Overall, the findings suggest that elevated burnout and work–family conflict coexist with moderate stress, satisfaction, and turnover intention, providing an important empirical basis for the subsequent structural model analysis.

Table 1: Levels of lecturer' stress, burnout, work-family conflict, satisfaction, and turnover intention

Variable	N	Mean	SD	Interpretation
Stress	387	3.45	0.790	Moderate
Burnout	387	3.60	0.776	High
Work-family conflict	387	3.52	0.808	High
Satisfaction	387	3.46	0.699	Moderate
Turnover intention	387	3.40	0.829	Moderate

Measurement model

Table 2 presents the reliability and convergent validity results at the construct level. All constructs exhibited strong internal consistency, with Cronbach's alpha and composite reliability values exceeding the recommended threshold of 0.70. In addition, average variance extracted (AVE) values ranged from 0.544 to 0.742, indicating adequate convergent validity (Hair et al., 2014, pp. 106-121). These results confirm that the measurement model meets established reliability and validity criteria and is suitable for subsequent structural model analysis.

Table 2: Reliability and convergent validity of major constructs

Construct	No. of Items	Cronbach's α	Composite Reliability (ρc)	AVE
Stress	21	0.900	0.920	0.589
Burnout	20	0.895	0.915	0.544
Work–family conflict	8	0.900	0.920	0.589
Satisfaction	4	0.814	0.877	0.641
Turnover intention	4	0.884	0.920	0.742

Note. All constructs demonstrate satisfactory internal consistency and convergent validity (Cronbach's α > 0.70, ρc > 0.70, AVE > 0.50).

Discriminant validity can be established when the square root of the average variation extracted (AVE) of a construct is greater than the correlation coefficient between the other constructs corresponding to it (Fornell & Larcker, 1981, pp. 39-50). Also shown in Table 3, the square roots of all AVEs in this study are greater than their corresponding correlation coefficients. Thus, this study has sufficient discriminant validity. HTMT is a new measure of discriminant validity, and an index of HTMT greater than 0.85 indicates the absence of discriminant validity (Henseler et al., 2015, pp. 115-135).

Table 3: Fornell–Larcker criterion

	IRPV	POP	IA	RS	TRB	SQ	IC	EE	PA	DEP	SAT	WC	TI
IRPV	**0.809**												
POP	0.366	**0.806**											
IA	0.428	0.431	**0.741**										
RS	0.391	0.400	0.397	**0.905**									
TRB	0.430	0.488	0.473	0.470	**0.803**								
SQ	0.367	0.404	0.378	0.376	0.491	**0.797**							
IC	0.368	0.335	0.350	0.323	0.377	0.345	**0.810**						
EE	0.059	0.096	0.066	0.091	0.090	0.062	0.098	**0.738**					
PA	0.029	0.147	0.077	0.135	0.145	0.079	0.103	0.525	**0.771**				
DEP	0.071	0.128	0.094	0.123	0.147	0.115	0.055	0.431	0.432	**0.821**			
SAT	-0.173	-0.116	-0.167	-0.174	-0.158	-0.145	-0.119	-0.236	-0.188	-0.157	**0.801**		
WC	0.057	0.024	0.049	0.059	0.049	0.011	0.052	0.021	0.040	0.030	-0.284	**0.767**	
TI	0.295	0.240	0.301	0.256	0.295	0.226	0.221	0.360	0.332	0.280	-0.655	0.193	**0.861**

Heterotrait-monotrait ratio (HTMT) as shown in Table 4 to explain and establish the discriminant validity. HTMT values, as shown in Table 4 ranged from 0.051 to 0.770; thus, the discriminant validity of this study was verified again.

Table 4: HTMT

	IRPV	POP	IA	RS	TRB	SQ	IC	EE	PA	DEP	SAT	WC
IRPV												
POP	0.499											
IA	0.559	0.564										
RS	0.515	0.530	0.502									
TRB	0.590	0.671	0.619	0.624								
SQ	0.506	0.558	0.501	0.503	0.682							
IC	0.499	0.456	0.455	0.424	0.515	0.475						
EE	0.075	0.119	0.087	0.109	0.114	0.080	0.121					

Table 4: (Counited) HTMT

	IRPV	POP	IA	RS	TRB	SQ	IC	EE	PA	DEP	SAT	WC
PA	0.052	0.186	0.099	0.165	0.186	0.100	0.134	0.595				
DEP	0.089	0.159	0.113	0.148	0.186	0.145	0.076	0.484	0.495			
SAT	0.220	0.146	0.203	0.219	0.204	0.190	0.151	0.272	0.222	0.183		
WC	0.075	0.051	0.063	0.072	0.081	0.046	0.067	0.064	0.054	0.056	0.329	
TI	0.365	0.298	0.357	0.308	0.369	0.285	0.274	0.405	0.379	0.316	0.770	0.215

Structural model

After establishing the reliability and validity, the researcher tested the hypotheses, as well as the direct and indirect effects by using SmartPLS 4.0 by applying the percentile bootstrap technique with iteratively resampling 5,000 times.

Table 5: Summary of hypothesis testing results

	Path	Original sample (O)	STDEV	T statistics	P values	Decision
H1	STR -> TI	0.222***	0.026	8.425	0.000	Supported
H1a	STR -> WC	0.062	0.037	1.652	0.099	Not Supported
H1b	STR -> BUR	0.162***	0.034	4.709	0.000	Supported
H1c	STR -> SAT	-0.165***	0.033	5.025	0.000	Supported
H2	WC -> TI	0.016	0.026	0.628	0.530	Not Supported
H2a	WC -> BUR	0.026	0.035	0.760	0.448	Not Supported
H2b	WC -> SAT	-0.266***	0.031	8.549	0.000	Supported
H3	BUR -> TI	0.237***	0.025	9.550	0.000	Supported
H3a	BUR -> SAT	-0.212***	0.033	6.491	0.000	Supported
H4	SAT -> TI	-0.543***	0.024	23.037	0.000	Supported

Hypothesis testing results shown in Table 5, it was found that WC cannot significantly influence TI ($\beta = 0.016$, $t = 0.628$, $p = 0.530$), while satisfaction is the strongest predictor of TI ($\beta = 0.543$, $t = 23.037$, $p = 0.000$). Besides, BUR ($\beta = 0.237$, $t = 9.550$, $p = 0.000$) and STR ($\beta = 0.222$, $t = 8.425$, $p = 0.000$) can also significantly influence TI. As for the hypotheses exploring the relationship between the mediator variables, we found that STR cannot significantly influence WC ($\beta = 0.062$, $t = 1.652$, $p = 0.099$). In contrast, it can significantly influence BUR ($\beta = 0.162$, $t = 4.709$, $p = 0.000$) and SAT ($\beta = -0.165$, $t = 5.025$, $p = 0.000$). WC cannot significantly influence BUR ($\beta = 0.026$, $t = 0.760$, $p = 0.448$), while it can significantly influence SAT ($\beta = -0.266$, $t = 8.549$, $p = 0.000$). BUR could also significantly influence SAT ($\beta = -0.212$, $t = 6.491$, $p = 0.000$).

Table 6: Indirect effects

Path	Specific indirect effects	STDEV	T statistics	P values
Stress -> WC -> TI	0.001	0.002	0.506	0.613
Stress -> WC -> Burnout -> TI	0.000	0.001	0.587	0.557
Stress -> WC -> SAT -> TI	0.009	0.006	1.610	0.107
Stress -> WC -> Burnout -> SAT -> TI	0.000	0.000	0.591	0.554
Stress -> Burnout -> TI	0.038***	0.009	4.137	0.000
Stress -> Burnout -> SAT -> TI	0.019***	0.005	3.803	0.000
Stress -> SAT -> TI	0.090***	0.018	4.976	0.000

Meanwhile, the researcher also analyzed the indirect effects of STR on TI under different paths. As shown in Table 6, of the seven pathways, three had significant indirect effects, with the strongest being 'Stress -> SAT -> TI' ($\beta = 0.090$, $t = 4.976$, $p = 0.000$), the second strongest being 'Stress -> Burnout -> TI' ($\beta = 0.038$, $t = 4.137$, $p = 0.000$), and the third being 'Stress -> Burnout -> SAT -> TI' ($\beta = 0.019$, $t = 3.803$, $p = 0.000$).

The coefficient of determination (R^2) serves as an evaluative metric that quantifies the extent to which the variance observed in the dependent variable can be accounted for by the independent variable (Cohen, 1988). In the current study, the R^2 of TI is 0.540, which indicates that all the independent variables (including the mediator variable) explain 54% of the variance of the dependent variable (TI). Q square (Q^2) is a metric used to judge the predictive relevance of the model, and when Q^2 is greater than 0, it has good predictive relevance. In the current study, the Q^2 of all predicted variables was greater than 0, which proves that the model has a good predictive relevance, with the critical variable TI having a Q^2 of 0.397. The F square (F^2) refers to the change in R^2 when an exogenous variable is removed from the model. When F^2 is greater than 0.02, the effect size is small; when F^2 is greater than 0.15, the effect size is medium; and when F^2 is greater than 0.35, the effect size is large (Cohen, 2014). For the dependent variable of TI, the F^2 of SAT is 0.537, with a high effect size; the F^2 of BUR and STR are 0.113 and 0.101, with a low effect size; and the F^2 of WC is only 0.001, which is a minimal effect of this exogenous variable on the R^2 of TI, almost none. The final model is showed in Figure 2.

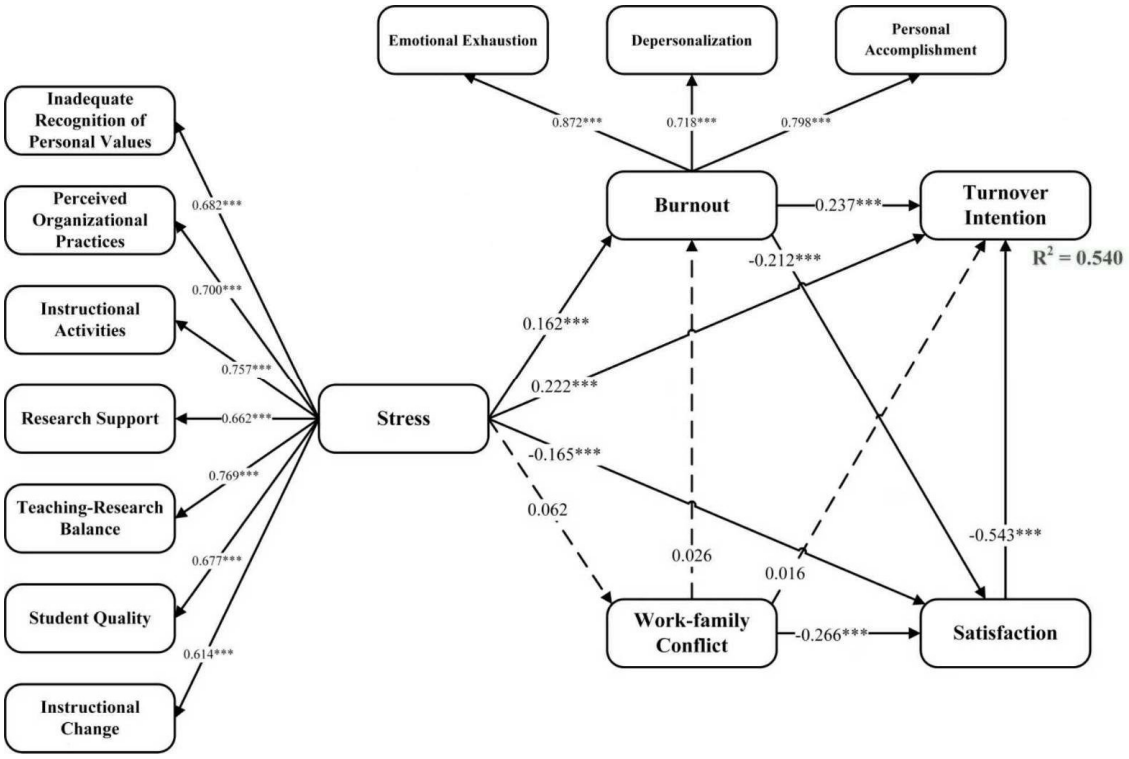

Figure 2: PLS results of this study

V. CONCLUSION AND DISCUSSION

This study confirms that stress is a critical determinant of turnover intention among Chinese university lecturers, directly increasing their likelihood of considering resignation. Burnout was found to significantly mediate this relationship, demonstrating that prolonged exposure to academic pressure leads to emotional exhaustion, disengagement, and diminished job satisfaction, ultimately heightening turnover intention. Job satisfaction emerged as the strongest negative predictor of turnover intention and was adversely affected by both stress and burnout, indicating a chain effect in which high stress increases burnout, burnout reduces satisfaction, and reduced satisfaction raises the desire to leave. In contrast, work-family conflict did not significantly mediate the relationship between stress and turnover intention, nor did it significantly predict burnout, although it negatively influenced job satisfaction. Overall, the findings highlight that stress reduction, burnout prevention, and satisfaction enhancement are essential for improving teacher retention in China's demanding higher education sector.

The study's findings align with extensive prior research demonstrating that stress is a major predictor of turnover intention in academic settings (Conley & You, 2009, pp. 771-780; Dorenkamp & Wei, 2018, pp. 747-767; Virtanen & Parpala, 2023, pp. 1-9). The intensification of academic evaluation systems, increased workload, and limited institutional resources continue to heighten faculty stress in China, which, in turn, fosters burnout and reduces job satisfaction (Little & Bartlett, 2002, p. 345; Zhang et al., 2019, pp. 414-435). The unexpected non-significant relationship between stress and work-family conflict contrasts with many Western findings (Cinamon & Rich, 2005, pp. 365-378; Rathi & Kumar, 2023, pp. 1-21) and may reflect the influence of collectivist cultural values and Confucian role ethics, which emphasize commitment, responsibility, and perseverance in both work and family roles (Lu & Gilmour, 2007, pp. 249-257). Similarly, the lack of a significant effect of work-family conflict on burnout and turnover intention suggests that Chinese university lecturers may tolerate work-life strain due to job security concerns, especially following the economic instability brought by COVID-19 (Blustein et al., 2020, pp. 1-4), and due to the high social status accorded to university teaching (Gao, 2008, pp. 154-165; Wang, 2020, pp. 1314-1328). Conversely, burnout's strong influence on both job satisfaction and turnover intention reinforces its central role in teacher well-being (Boamah et al., 2022, p. 809; Christian-Brandt et al., 2020, pp. 104-117). As burnout erodes emotional resources, professional fulfillment, and social support, it substantially lowers satisfaction and increases withdrawal tendencies. The study ultimately underscores the need for universities to reduce excessive job demands, provide greater organizational support, and strengthen professional recognition to safeguard teacher well-being and retention.

SUGGESTION

Based on the findings of this study, university administrators and policymakers should adopt targeted strategies to help lecturers manage stress and burnout without compromising work efficiency or academic productivity. Given that burnout and reduced job satisfaction—rather than work–family conflict—were the primary mechanisms linking stress to turnover intention, institutional interventions should focus on psychological sustainability and organizational support. Universities are encouraged to optimize workload allocation and performance evaluation systems by reducing excessive emphasis on short-term research output and recognizing diverse academic contributions, including teaching quality and service roles. Strengthening organizational support through counseling services, stress-management programs, and supportive leadership practices can further mitigate burnout and sustain long-term engagement. At the policy level, higher education authorities should promote governance frameworks that emphasize stable employment, transparent promotion pathways, and balanced accountability, thereby aligning institutional effectiveness with lecturer well-being and ensuring sustainable performance in the academic workforce. For future research, longitudinal studies are highly recommended to explore how stress, burnout, and job satisfaction evolve over time and influence turnover intention in different career stages. Such studies could provide stronger evidence of causality and allow researcher to detect changes and trends more accurately.

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THE DEVELOPMENT OF A CURRICULUM AND CARTOON-BASED LEARNING MODULES FOR AN ADDITIONAL COURSE: MUEANG FA DAET SONG YANG AND PHRA THAT YAKHU TO PROMOTE 21ST-CENTURY CAREER SKILLS FOR GRADE 7 STUDENTS

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ABSTRACT

This research aimed to develop and implement a curriculum and a set of cartoon-based learning modules for the supplementary course *"Mueang Fa Daet Song Yang and Phra That Yakhu"* to promote 21st-century career skills among Grade 7 students at Kamalasai School, Kalasin Province. The study employed a research and development (R&D) methodology comprising four stages: basic information analysis, curriculum and learning material development, field implementation, and evaluation. The research instruments included the developed curriculum, nine cartoon-based learning booklets, lesson plans, assessment forms, and a student satisfaction questionnaire. Content validity was examined by five experts using the Index of Item-Objective Congruence (IOC). The instructional materials achieved efficiency values exceeding the established criterion of 80/80 (E_1/E_2 = 83.54/81.43). The results indicated that students' post-test achievement scores were significantly higher than their pre-test scores, with 100% of the students meeting the learning criteria. In addition, students demonstrated marked improvement in analytical thinking, collaboration, and technology use, reflecting the development of key 21st-century career skills. Students' overall satisfaction with the learning modules was rated at the highest level across all aspects, particularly content, learning activities, and media design. These findings suggest that cartoon-based learning effectively enhances active learning, engagement, and skill development while integrating local wisdom and community identity. The developed curriculum and learning modules therefore have strong potential as a model for promoting 21st-century career skills through innovative and contextually relevant educational practices.

Keywords: Curriculum development, Cartoon-based learning modules, Mueang Fa Daet Song Yang, Phra That Yakhu, 21st century career skills

I. INTRODUCTION

Education in the 21st century emphasizes the cultivation of essential career skills that enable learners to adapt to rapid technological, social, and economic change. These core competencies creativity, collaboration, communication, and critical thinking are vital for preparing youth to participate effectively in an increasingly competitive world (Buason, 2019, pp. 1–11). In Thailand, contemporary educational policies and competency-based education reforms increasingly emphasize learner-centered instruction, innovation, and the integration of real-world contexts to enhance problem-solving abilities and career readiness. At the same time, integrating local wisdom and community identity into school curricula has been recognized as an important approach to promoting sustainable learning and strengthening cultural appreciation (Boonapai et al., 2008, p. 17).

A number of studies have explored instructional innovation and curriculum design that promote 21st-century learning skills. Bunnak (2023, pp. 25–60) developed an art-learning module based on postmodern art concepts, which enhanced students' creativity and metacognitive abilities. Likewise, Phosue (2020, pp. 10–25) designed a curriculum to improve secondary-school teachers' learning-management competencies for the digital era. These studies demonstrate that integrating modern teaching methods and engaging media can improve learners' motivation and achievement. However, research that systematically integrates local cultural and historical contexts with the development of 21st-century career skills particularly through cartoon-based learning modules remains limited.

This study was grounded in the curriculum-development frameworks proposed by Tyler (1949, pp. 1–3) and Taba (1962, pp. 12–13), which emphasize defining educational objectives, selecting and organizing learning experiences, and evaluating learning outcomes. Sayler and Alexander (1974, pp. 45–46) also stressed that effective curricula should bridge theoretical principles with practical classroom applications. Building on these frameworks, the present study integrates local wisdom as a meaningful learning context that supports both cultural understanding and the development of 21st-century career skills. Mueang Fa Daet Song Yang and Phra That Yakhu are significant cultural and historical heritage sites in Kalasin Province, representing community identity, traditional knowledge, and local artistic expression. These sites provide authentic learning resources that can enhance students' engagement and understanding by connecting academic content with familiar real-life contexts.

Therefore, this study aimed to develop and implement a supplementary curriculum and cartoon-based learning modules for Grade 7 students at Kamalasai School, Kalasin Province, integrating local cultural heritage with innovative instructional media. Through this approach, students were expected to enhance 21st-century career skills, including analytical thinking, collaboration, creativity, and technology use, while simultaneously cultivating appreciation for local culture and community identity.

II. LITERATURE REVIEW

Curriculum development is a systematic process of planning, designing, implementing, and evaluating learning experiences based on educational goals and learners' needs. According to Tyler (1949, pp. 1-3), curriculum development involves defining objectives, selecting learning experiences, organizing content, and evaluating outcomes. Similarly, Taba (1962, pp. 12-13) proposed a grassroots approach emphasizing teachers' roles in designing learning experiences. Sayler and Alexander (1974, pp. 45–46) suggested that effective curricula should integrate theory with practice to promote meaningful learning. In the context of Thailand, (Buason, 2019, pp. 1–11) highlighted that 21st-century curriculum design should focus on innovation, creativity, and problem-solving to prepare learners for future challenges. These curriculum development theories emphasize the systematic alignment of objectives, learning activities, and evaluation processes to support learners' skill development in contemporary educational contexts.

Previous studies have demonstrated various approaches to developing curricula and instructional materials aimed at enhancing learning effectiveness. Bunnak (2023, pp. 25-60) developed an art learning module based on postmodern art concepts that improved students' creativity and metacognitive skills, while (Phosue, 2020, pp.10–25) designed a digital learning management curriculum to enhance teachers' professional competencies. These studies indicate that curriculum development supported by creative and innovative instructional approaches can positively influence learners' cognitive and metacognitive outcomes. In addition, the use of visual and media-based instructional materials has been recognized as an effective approach to enhancing learner engagement and understanding. (Raiyn, 2016, pp. 115-121) Furthermore, curriculum development that incorporates local contexts and learning environments can enhance the relevance of learning experiences. Local wisdom and cultural heritage can function as meaningful learning resources that help learners connect academic knowledge with real-life experiences and community identity (Boonapai et al., 2008, p. 17). When local cultural content is systematically integrated into curriculum design, it can support learner engagement and provide authentic contexts for developing essential skills. (Pewewardy, 2002, pp.22–56) Therefore, this study was based on the conceptual framework of Tyler (1949, pp. 1–3) and Taba (1962, pp. 12–13), focusing on curriculum development principles and the integration of local wisdom within a structured curriculum model to create a relevant learning model for Grade 7 students.

III. RESEARCH METHODOLOGY

The research instruments included a supplementary curriculum, cartoon-based learning modules, a curriculum and lesson evaluation form, a 21st-century career skills assessment form, and a student satisfaction questionnaire. The supplementary curriculum and cartoon-based learning modules were designed and developed by the researcher. The modules consisted of nine cartoon booklets presenting content related to the history, culture, and local learning resources of Mueang Fa Daet Song Yang, aiming to promote students' engagement and understanding through visual storytelling.

The curriculum and lesson evaluation form was used by five experts to assess the appropriateness of the content, format, and media of the developed materials. The 21st-century career skills assessment form was employed to measure students' analytical thinking, collaboration, technology use, and self-directed learning before and after the instructional implementation. In addition, the student satisfaction questionnaire was used to evaluate learners' opinions and levels of satisfaction toward the cartoon-based learning modules.

All research instruments were constructed by the researcher based on relevant educational theories and the results of a needs analysis. The instruments were reviewed by five experts in curriculum and instructional design to examine content validity using the Index of Item-Objective Congruence (IOC)**.** Items with IOC values of 0.50 or higher were accepted, while those scoring below the criterion were revised or removed. The 21st-century career skills assessment form and the satisfaction questionnaire were piloted with a sample group similar to the actual participants. Their reliability was examined using Cronbach's Alpha Coefficient**,** which yielded reliability values of $\alpha \geq 0.80$, indicating satisfactory internal consistency.

The data collection process was conducted in three phases**.** In **the** pre-experimental phase**,** students' 21st-century career skills were assessed using the pre-test version of the assessment form**.** During the experimental phase, instructional implementation was carried out using the nine cartoon-based learning booklets following the sequence of learning units specified in the developed curriculum**.** In the post-experimental phase, students' learning achievement and 21st-century career skills were reassessed and compared with the pre-test results**.** Additional data were collected through the student satisfaction questionnaire, teacher interviews, and open-ended feedback to obtain in-depth insights into students' learning outcomes and the effectiveness of the instructional implementation. Throughout the research process, the researcher observed students' learning behaviors, recorded field notes, and analyzed qualitative data to support the improvement of the learning materials for future use.

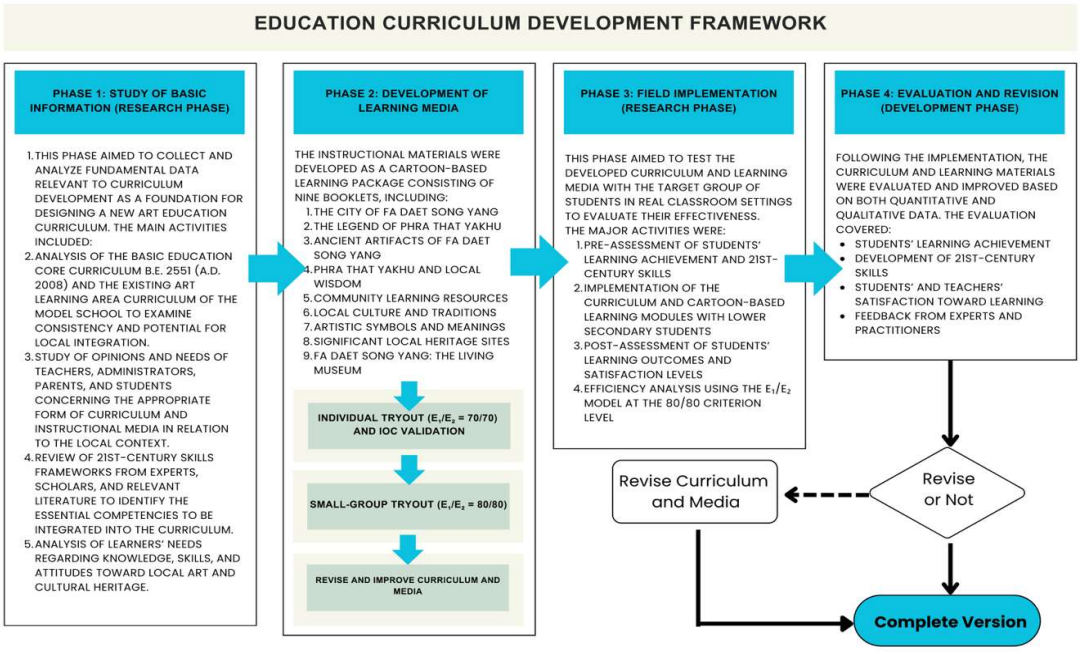

Figure 1: Conceptual Framework of the Research

IV. DATA ANALYSIS

The data obtained from this study were analyzed using both quantitative and qualitative methods to comprehensively evaluate the effectiveness of the developed curriculum and cartoon-based learning modules.

Quantitative data were analyzed using descriptive statistics, including mean, percentage, and standard deviation. Students' learning achievement and 21st-century career skills were analyzed by comparing pre-test and post-test scores to determine learning effectiveness after the instructional implementation. In addition, the efficiency of the developed curriculum and cartoon-based learning modules was evaluated using the E_1/E_2 efficiency criteria**,** with the standard criterion set at 80/80**.**

Qualitative data were collected from student satisfaction questionnaires, teacher interviews, open-ended feedback, and classroom observations. These data were analyzed using content analysis to identify common themes related to students' learning behaviors, engagement, and perceptions toward the instructional activities. Field notes recorded during the instructional process were also examined to support the interpretation of quantitative results and to provide additional insights for improving the learning materials.

V. RESULTS

The study on the development of a supplementary curriculum and cartoon-based learning modules entitled "Mueang Fa Daet Song Yang and Phra That Yakhu" aimed to promote 21st-century the 21st-century career skills among Grade 7 students. The results of data analysis and curriculum development are presented descriptively and in tabular form, and are summarized in four main stages as follows.

Stage 1: Results of Curriculum and Cartoon-Based Learning Module Development

The results of the curriculum and cartoon-based learning module development were derived from the analysis of basic information and were used as guidelines for designing the supplementary curriculum and instructional materials. The findings revealed a shared consensus among administrators, teachers, parents, and students that cartoon media should be used as the primary instructional tool to promote enjoyable, engaging, and easily comprehensible learning experiences while fostering local knowledge and 21st-century career skills.

The supplementary curriculum and the cartoon-based learning modules entitled *"Mueang Fa Daet Song Yang and Phra That Yakhu"* were developed through a systematic process consisting of curriculum design, content development, expert validation, and preliminary efficiency testing. The results of this stage are presented as follows.

1.1 Results of Curriculum and Learning Module Quality Evaluation The researcher developed the curriculum framework, nine cartoon-based learning booklets, and lesson plans based on the objectives of the supplementary course. These materials were submitted to five experts for quality evaluation, including a curriculum and instruction specialist, a cultural arts specialist, an educational technology expert, an experienced art teacher, and a curriculum development supervisor.

The evaluation results indicated that all components of the curriculum and cartoon-based learning modules achieved an Index of Item-Objective Congruence (IOC) value of 1.00. This finding demonstrates that the developed curriculum and instructional materials were accurate, comprehensive, and appropriate in terms of content, structure, and instructional media, and were suitable for implementation in actual educational settings.

1.2 Results of Preliminary Efficiency Testing (E1/E2)

After revising the curriculum and learning modules according to the experts' suggestions, the researcher conducted a preliminary efficiency test using individual and group tryouts. The purpose of this testing was to determine the initial effectiveness of the cartoon-based learning modules prior to field implementation. The results of the preliminary efficiency test are presented in Table 1

Table 1 : Results of the Preliminary Efficiency Test of the Cartoon-Based Learning Modules (E_1/E_2)

Type of Tryout	Number of Students	Full Score	Mean	SD	Efficiency (%)
Individual Tryout (E_1)	3	60	43.67	5.03	72.78
Individual Tryout (E_2)	3	40	28.67	5.69	71.67
Group Tryout (E_1)	9	60	43.89	4.96	73.15
Group Tryout (E_2)	9	40	33.22	2.77	83.06

The findings showed that the individual tryout achieved efficiency values of 72.78/71.67, while the group tryout achieved efficiency values of 73.15/83.06**.** When compared with the established criterion of 70/70 for preliminary efficiency testing, both tryouts exceeded the standard.

These results indicate that the cartoon-based learning modules demonstrated satisfactory process efficiency (E_1) and learning outcome efficiency (E_2), and were therefore considered appropriate for use in the field tryout stage.

1.3 Analysis of the Lesson Plans

The lesson plans integrated within the cartoon-based learning modules were also evaluated by the experts. The results showed that the lesson plans were consistent with the stated objectives, learning activities, and expected learning outcomes in all aspects.

The experts suggested only minor revisions, primarily focusing on increasing the variety of learning activities and ensuring that the activities were suitable for the developmental level of Grade 7 students. After incorporating these suggestions, the lesson plans were considered ready for implementation.

Stage 2: Results of the Field Tryout

After the curriculum and the cartoon-based learning modules were reviewed and revised according to the experts' recommendations, the researcher conducted a field tryout with 40 Grade 7 students from Kamalasai School. The instructional implementation was carried out in accordance with the lesson schedule specified in the developed curriculum.

2.1 Results of the Efficiency of the Learning Modules (E_1/E_2)

The results of the field tryout are presented in Table 2

Table 2 : Results of the Field Tryout Efficiency Test of the Cartoon-Based Learning Modules (E_1/E_2)

Type of Tryout	Number of Students	E1 (%)	E2 (%)
Field Tryout	40	83.54	81.43

The analysis of the learning module efficiency, based on the field implementation with 40 Grade 7 students**,** revealed the following results:

1. The E_1 value was 83.54**,** indicating that during the learning process, students correctly completed 83.54% of the learning activities and exercises**.**

2. The E_2 value was 81.43, meaning that after the instruction, students correctly answered 81.43% of the achievement test items.

When compared with the standard criterion of 80/80, it was found that both efficiency values were higher than the established standard, demonstrating that the cartoon-based learning modules were of excellent quality, capable of promoting effective and sustainable learning outcomes, and suitable for practical use in school settings.

2.2 Learning Achievement Before and After Instruction

The analysis of the pre-test and post-test results showed that students' learning achievement after instruction was higher than before instruction, with a statistically significant difference. Moreover, all students (100%) met the achievement criteria, indicating a substantial improvement in learning performance following the implementation of the curriculum and learning modules.

2.3 Students' Satisfaction

Data collected on students' satisfaction toward the cartoon-based learning modules revealed that their overall satisfaction level was at the "highest" level across all evaluated aspects, including learning media, content, learning activities, and teachers' instructional methods.

Summary of Field Tryout Findings

The field implementation of the curriculum and cartoon-based learning modules with Grade 7 students at Kamalasai School demonstrated that:

1. The learning modules achieved efficiency values higher than the 80/80 standard (E_1/E_2 = 83.54/81.43 > 80/80).
2. Students' post-test learning achievement was higher than their pre-test results, and all students (100%) met the passing criteria.
3. Students expressed the highest level of satisfaction toward the learning modules.

These results confirm that the cartoon-based learning modules were of high quality and suitable for real classroom use. Furthermore, they have the potential to serve as a model for developing learning media for other supplementary subjects in the future.

Stage 3: Results of the Curriculum Evaluation and Improvement

After completing the field implementation of the curriculum and the cartoon-based learning modules, the researcher conducted an evaluation covering three main aspects: (1) students' learning achievement, (2) 21st-century career skills, and (3) students' opinions and satisfaction toward the learning experience. The evaluation results were subsequently used to revise and improve the curriculum and learning modules for future application.

3.1 Learning Achievement

The analysis of pre-test and post-test scores from 40 Grade 7 students revealed that the mean post-test score was significantly higher than the pre-test score. Moreover, all students (100%) met the passing criteria, indicating that the curriculum and cartoon-based learning modules effectively enhanced students' learning achievement.

Table 3 : Comparison of Students' Learning Achievement Before and After Instruction

Test	N	Mean ($\bar{x}$)	Percentage Meeting the Criterion
Before Learning	40	Below the criterion	–
After Learning	40	Above the criterion	100%

Table 3 shows that the post-test learning achievement of the 40 Grade 7 students at Kamalasai School was significantly higher than their pre-test achievement, indicating a statistically significant improvement in learning outcomes. Importantly, all students (100%) met the required performance criteria, demonstrating that the cartoon-based learning modules were of high quality and had a positive effect on enhancing students' academic achievement.

3.2 Evaluation of 21st-Century Career Skills

The evaluation of 21st-century career skills among the Grade 7 students after implementing the curriculum and cartoon-based learning modules revealed that students demonstrated notable improvement in all assessed skill areas compared with their performance before instruction. The most significant gains were observed in analytical thinking, problem-solving, and collaboration skills, reflecting students' ability to engage in active learning and apply knowledge to real-world contexts.

The assessment was conducted using a 21st-century career skills evaluation form developed by the researcher, which had been validated by experts for content validity and reliability. The post-instruction results indicated that students' performance was rated at a "very good" level across all skill dimensions, including technological literacy, creative production, and group communication.

These findings are consistent with the framework proposed by Trilling and Fadel (2009, pp. 48–49), which defines 21st-century career skills as comprising Learning and Innovation Skills, Information, Media, and Technology Skills, and Life and Career Skills. These components were clearly demonstrated through students' learning experiences with the cartoon-based learning modules.

The use of cartoon-based learning modules enabled students to learn about local history and culture while simultaneously developing analytical thinking through story interpretation, practicing teamwork through group activities, and enhancing technological skills through online research. Together, these skills represent essential competencies for future learning and career readiness.

3.3 Students' Opinions and Satisfaction

The assessment of students' opinions and satisfaction toward the curriculum and cartoon-based learning modules revealed that the overall satisfaction level was rated at the "highest" level across all evaluated aspects, including learning media, content, learning activities, and teaching methods. This finding indicates that students responded positively to the learning experience and perceived the instructional materials as engaging and effective in supporting their learning.

Table 4 : Results of Students' Satisfaction Evaluation

Evaluation Aspect	Level of Satisfaction
Content and Learning Materials	Highest
Learning Activities	Highest
Attractiveness of the Cartoon Media	Highest
Teacher's Teaching Methods	Highest
Overall	Highest

The results in Table 4 showed that students expressed the highest level of satisfaction particularly with the attractiveness of the cartoon media and the engaging learning activities, indicating that the cartoon-based learning modules effectively responded to students' needs and interests and provided a learning experience that was both enjoyable and meaningful.

3.4 Improvement of the Curriculum and Cartoon-Based Learning Modules

Based on the recommendations from experts, teachers, and students, the curriculum and learning modules were revised in the following areas:

1. Diversifying learning activities to better accommodate individual differences among students.

2. Adding explanatory captions to the cartoon illustrations to enhance clarity and understanding of the content.
3. Refining assessment items to ensure greater clarity and closer alignment with the intended learning objectives.

Summary of Evaluation Findings

The evaluation of the curriculum and the cartoon-based learning modules revealed that:

1. Students' post-test learning achievement was higher than their pre-test scores**,** with 100% of students meeting the achievement criteria**.**
2. Students demonstrated notable improvement in 21st-century career skills across all dimensions**.**
3. Students' satisfaction toward the learning modules was rated at the highest level in all aspects**.**
4. The curriculum and cartoon-based learning modules were further refined in terms of learning activities, explanatory materials, and assessment tools.

It can therefore be concluded that the developed curriculum and cartoon-based learning modules were of high quality, appropriate, and practically applicable in educational settings. Furthermore, they have the potential to serve as a prototype for developing other supplementary curricula in various subject areas in the future**.**

VI. CONCLUSION AND DISCUSSION

The results of this research indicate that the development of the supplementary curriculum and cartoon-based learning modules entitled *"Mueang Fa Daet Song Yang and Phra That Yakhu"* was effective in enhancing both learning achievement and 21st-century career skills among Grade 7 students. Integrating local history and cultural content through cartoon-based media enhanced students' engagement and understanding by connecting learning content with familiar community contexts. The efficiency results from the field tryout (E_1/E_2 = 83.54/81.43) exceeded the 80/80 criterion, and all students (100%) met the achievement criteria after instruction, demonstrating the effectiveness of the instructional design. In addition, students showed notable improvement in analytical thinking, technology use, and collaboration skills, and expressed the highest level of satisfaction toward the learning modules. These findings are consistent with curriculum development frameworks emphasizing systematic design and evaluation (Tyler, 1949; Taba, 1962), the integration of local contexts in learning media (Buason, 2019; Bunnak, 2023), and the 21st-century skills framework proposed by Trilling and Fadel (2009).

In conclusion, this study demonstrates that combining local cultural identity with cartoon-based learning media can provide meaningful learning experiences that enhance academic achievement and essential 21st-century career skills. The developed curriculum and learning modules effectively responded to learners' needs and can serve as a practical instructional model for supplementary subjects integrating local wisdom with modern learning approaches. Furthermore, the curriculum may be adapted for use in other subject areas or educational contexts to promote student engagement, skill development, and readiness for future learning and career demands.

VII. SUGGESTION

Based on the findings of this research, the developed curriculum and cartoon-based learning modules should be applied in supplementary courses or learning activities that integrate local history and cultural heritage with skill development, as the instructional design effectively enhances students' engagement, learning achievement, and 21st-century career skills. Teachers are encouraged to adapt the cartoon-based learning modules for different subject areas and learning contexts, particularly those emphasizing creativity, collaboration, and analytical thinking, and to modify learning activities and assessment methods to suit learners' developmental levels and individual differences. In addition, educational institutions and curriculum developers may use the results of this study as a guideline for designing learning media that combine local wisdom with modern instructional approaches in order to promote meaningful learning experiences while preserving cultural identity. Finally, future research should investigate the long-term effects of cartoon-based learning modules on students' learning outcomes and skill development, as well as explore their application across different educational levels and subject areas to enhance the broader applicability of curriculum and instructional media development.

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THE NEXUS OF TPACK, SAMR, AND 21ST-CENTURY SKILLS IN DIGITAL MATHEMATICS EDUCATION: AN INTEGRATIVE REVIEW

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ABSTRACT

The current 21st-century Mathematics curriculum has raised major questions regarding the fostering of analytical reasoning, problem-solving, and the application of mathematical skills in practice. Digital technologies, particularly digital mathematics tools, have a significant impact on the creation and enhancement of quality, relevance, and engagement in mathematics learning, in line with Education 4.0. This study conducts an integrative literature review (ILR) and a conceptual synthesis using the TPACK, SAMR, and 21st-century skills (4Cs) frameworks. A systematic review of peer-reviewed literature published between 2015 and 2025 was carried out, leading to the selection of 26 research papers from international and Thailand-based databases, including Scopus, Web of Science, ERIC, and ThaiJO. Data were extracted and coded based on (i) integrated TPACK characteristics, (ii) SAMR-categorized task transformation degrees, and (iii) 4Cs outcome benchmarks. Findings indicate that while digital tools support conceptualization, higher-order 4Cs outcomes emerge most consistently when technology use reaches the Modification and Redefinition levels, mediated by strong integrated TPACK. Conversely, Substitution or Augmentation levels tend to yield functional improvements without producing transformational outcomes. The review concludes by recommending holistic instructional design principles that explicitly connect technology affordances to intended 4Cs outcomes, offering practical implications for teacher professional development and digital mathematics education in Thailand and beyond.

Keywords: Digital technology, Digital mathematics education, 21st-century skills, TPACK framework, SAMR model

I. INTRODUCTION

In the 21st century, digital technologies have become indispensable in every branch of human life, and not only in the field. As a result, contemporary schools are focused on developing skills that are fundamental to life and career among a growing group of students, collectively referred to as 21st-century skills. The 4Cs (Critical Thinking, Collaboration, Communication, and Creativity) are most important among these; mathematics instruction must move away from procedural fluency and toward deeper analytical reasoning and application in the real world. This educational transformation supports Thailand's national strategy, "Thailand 4.0", which aims to drive the country's development as a result of innovation and enhance the capabilities of high-quality human capital for the digital era. Accordingly, technology integration is no longer a choice but an essential pedagogical necessity that influences curriculum and instructional practices in mathematics education.

Over the last 20 years, international interest in the transformative power of digital tools to support mathematical education has increased. Indeed, the potential positive effect of technology on student understanding and inquiry-based learning via tools like visualization, dynamic manipulation, and immediate feedback is evidenced (Cheung & Slavin, 2013, pp. 88-113; Drijvers et al., 2010, pp. 213-234; Hoyles, 2018, pp. 209-228). The use of dynamic mathematical software such as GeoGebra, Desmos, and other Dynamic Mathematics Software (DMS) tools has been reported to empower learners to problem-solve, understand mathematics, and engage in high-level thinking through exploratory modeling activities (Drijvers et al., 2010, pp. 213-234; Hoyles, 2018, pp. 209-228). In fact, DMS reduces cognitive load (difficult calculations and visualizations), freeing up mental power for analytical thinking and deep conceptual exploration. Additionally, meta-analytic studies indicate that learning environments enhanced by technology offer greater educational benefits than traditional teaching methods, especially when technology supports the interactive construction of knowledge. (Cheung & Slavin, 2013, pp. 88-113). Yet, despite all this evidence supporting integration, several reviews indicate that the use of technology in mathematics teaching is generally cosmetic and not meaningful enough for the 4Cs of transformation to take place (Critical Thinking, Collaboration, Communication, Creativity). Such failure is often directly associated with the marginal use of pedagogical interventions informed by the SAMR (Substitution, Augmentation, Modification, Redefinition) model, where the use of technology seldom progresses beyond the Substitution (S) or Augmentation (A) level (Aldosemani, 2019, pp. 46-53; Hamilton et al., 2016, pp. 433-444). Hence, the literature underlines that the successful application of technology potential to 21st-century skills development is an overall reflection on the teacher's integrated knowledge base, as proposed by the TPACK framework of Koehler et al. (2011, pp. 13-19). This calls for coherent pedagogical frameworks which directly foreground the thoughtful and transformative contribution of the emergence of new technologies to mathematics teaching.

There have been rapid changes in the digital transformation of education in Thailand from 2010 through the emergence of mobile and hybrid learning in the post–COVID-19. Despite the significant usage of digital tools, empirical evidence from the Office of the Education Council (Office of the Education Council [OEC], 2023) points to an ongoing implementation gap where technology is embedded in lower substitution and augmentation levels of mathematics classrooms. This is not simply a lack of technology, but rather an extreme pedagogical deficiency, characterized by the absence of strategic, purposeful, and powerful infusion to promote the learning of the 4Cs. To address this challenge, teachers need to intentionally build their capacity to integrate technology through expertise with TPACK in a deliberate way — via ongoing professional development and reflective practice to achieve

meaningful and innovative learning experiences (Drugova et al., 2021, pp. 4923–4948; Muslimin et al., 2023, pp. 1-15; Polly & Orrill, 2012, pp. 1-32).

In response to the growing educational demands, this article presents an Integrative Literature Review (ILR) on the connections between the TPACK framework (Technological Pedagogical Content Knowledge), the SAMR model (Substitution, Augmentation, Modification, and Redefinition), and 21st-century skills, within digital mathematics education. A total of 26 peer-reviewed papers from international and Thai-based databases, such as Scopus, Web of Science, ERIC, and ThaiJO, were chosen from a systematic review of peer-reviewed studies published between 2015 and 2025. The objectives of this study are to: (1) synthesize evidence on how digital mathematics tools are integrated in mathematics teaching and learning; (2) categorize reviewed studies according to integrated TPACK characteristics, SAMR-categorized degrees of task transformation, and 4Cs outcome benchmarks; (3) identify cross-study patterns indicating the conditions under which higher-order 4Cs results most reliably appear, especially when technology use reaches the Modification and Redefinition levels and is mediated by strong integrated TPACK; and (4) propose design principles aligning technology affordances with 4Cs outcomes to inform teacher professional development and digital mathematics education.

II. LITERATURE REVIEW

The 21st-century skills model presents it as an underlying model to facilitate the preparation of learners to succeed in a digital, knowledge-dominated society. Within this framework are the "4Cs" – Critical Thinking, Creativity, Communication, and Collaboration – which are at the heart of global educational transformations including those practiced in Thailand, to develop innovative and self-motivated learners (Binkley et al., 2012, pp. 17-66; Scott, 2015, Online; Voogt & Pareja Roblin, 2012, pp. 299-321). In mathematics education, these skills necessitate a pedagogical shift away from procedural fluency toward the building of analytical reasoning, complex problem-solving, and collaborative inquiry (Hoyles, 2018, pp. 209-228). Digital technologies—such as GeoGebra and the Desmos suite — are crucial for helping students visualize mathematical processes, work with real-world datasets, and dynamically alter variables, all of which contribute to better conceptual comprehension. There is broad evidence that technology-enriched learning environments encourage conceptual understanding, exploratory thinking, and higher-order decision-making (Steenbergen-Hu & Cooper, 2013, pp. 970-987). Research using Dynamic Mathematics Software (DMS) has shown its potential to help students to construct and test mathematical relationships interactively (Drijvers et al., 2010, pp. 213-234; Juandi et al., 2021, pp. 1-8). Additionally, simulation, modeling, and game-based simulations may activate inquiry, perseverance, and problem-solving—the essential aspects of the 4Cs in particular (Ke, 2014, pp. 26-39; Tishkovskaya & Lancaster, 2012, pp. 1-56). Together, these empirical studies underscore the importance of planning mathematics-rich, technology-engendered tasks that facilitate rich, deep, and holistic engagement as well as conceptual understanding, a need that remains paramount in Thailand, given that national evaluations remain dominated by struggles in terms of students' comprehension and problem-solving skills (OEC, 2023).

In support of this empirical evidence, theoretical frameworks such as Technological Pedagogical Content Knowledge (TPACK) and the SAMR model (Substitution, Augmentation, Modification, Redefinition) provide solid analytical bases for analyzing (and categorizing) teachers' meaningful integration of technology in mathematics teaching (see Koehler et al., 2013, pp. 13-19). Research incorporating TPACK underscores that successful integration necessitates that educators synthesize technology, pedagogical, and content knowledge, and plan learning activities aimed at fostering critical thinking ability, inquiry, and discourse, instead of simply using mechanical materials (Chai et al., 2013,

pp. 31-51; Tondeur et al., 2017, pp. 555-575). In contrast, research using the SAMR framework often demonstrates that classroom technology use remains marginal, focusing on the lower-level Substitution or Augmentation stages, with limited pedagogical impact (Hamilton et al., 2016, pp. 433-441; Aldosemani, 2019, pp. 46-53). To support the 4Cs, the above integration levels (Modification and Redefinition) must be attained, however, this transformation needs combined TPACK competence across teachers (Drijvers et al., 2010, pp. 213-234; Abbitt, 2011, pp. 281-300). Although Thailand's Education 4.0 emphasizes 21st-century competencies, empirical evidence has shown that most Thai mathematics teachers still remain primarily at the augmentation stage, and only a small group progresses to the redefinition stage (OEC, 2023; Muslimin et al., 2023, pp. 1-15). To develop efficient technology integration in education and student-centered learning outcomes, this gap remains, and sensible policies and PD supported by empirical studies to show how TPACK, SAMR, and the 4Cs relate are required. (Abar & Almeida, 2025, pp. 1-8; Drugova et al., 2021, pp. 4923–4948; Theodorio et al., 2024, pp. 1-18). The objective of this integrative review is to synthesize theoretical and empirical views, establishing an integrated and practical perspective that advances digital mathematics education in Thailand and the broader educational environment, and ultimately contributes to supporting both educators and policymakers in the effective use of digital mathematical tools.

III. RESEARCH METHODOLOGY

This study utilized an intensive approach of an Integrative Literature Review (ILR)—a systematic framework used to collect, analyze, and synthesize knowledge from multiple academic sources. By using the ILR method, an all-inclusive, evidence-based picture of digital technologies—specifically digital mathematics tools—was developed regarding digital mathematics education. This analysis was firmly rooted in the theoretical context of TPACK (Technological Pedagogical Content Knowledge), the SAMR model (Substitution–Augmentation–Modification–Redefinition), and 21st-century skills, which were specifically identified by means of the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity). The ILR approach was chosen because it enables the combination of findings from different research perspectives (both theoretical and empirical) and generates new interpretation results and conceptual insights beyond those of individual studies.

3.1 Literature search strategy and selection criteria

To ensure methodological rigor, relevance, and currency, a systematic search was conducted using major academic databases (Scopus, Web of Science (WoS), ThaijO, and ERIC) for the period 2015–2025. This era was selected to ensure up-to-date research on the current state of digital transformation in mathematics education, capturing recent trends, innovations, and empirical findings relevant to the integration of technology in classrooms. Boolean operators (AND, OR) were used to generate multiple search terms of these three main conceptual bases (Technology, Pedagogy/Content, and Frameworks). The representative search strings included: [Domain 1: Technology] ("Digital Technology" OR "Digital Tool" OR "App") AND [Domain 2: Content/Context] ("Mathematics Education" OR "Mathematics Teaching") AND [Domain 3: Conceptual Frameworks & Skills] ("TPACK" OR "SAMR" OR "Critical Thinking" OR "Collaboration" OR "21st Century Skills"). To guarantee quality, focus, and consistency, explicit inclusion/exclusion criteria were specified. For inclusion criteria were: (a) the application of digital technologies or digital mathematics tools in mathematics teaching and learning; (b) implementation or discussion of the TPACK and/or SAMR models; (c) a tangible emphasis on the cultivation of 21st-century skills – in particular the 4Cs; (d) peer review of and publications within credible academic journals (e.g., indexed in Scopus, Web of Science, ERIC and Thai Journals Online), and (e) published in English or Thai languages within the identified time frame. Studies that (a) did not focus on any digital

technology integration directly into mathematics education, (b) were not methodologically transparent or did not provide in-depth empirical evidence, (c) were based mainly on opinions, or (d) had redundant data or repeated their findings were discarded.

3.2 Analytical process and conceptual synthesis

A rigorous three-phase analytical process, encompassing categorization, content analysis, and conceptual synthesis, was employed. In our coding process, we systematically categorized the included studies into thematic clusters for various types of digital tools, pedagogical applications, learner outcomes, and technological integrations using the SAMR model as the principal structuring model. Within content analysis, significant themes, repeated patterns, and emergent ideas were systematically uncovered as ways in which digital tools facilitate conceptual understanding, exploratory learning, and the development of the 4Cs—for example, through facilitating collaborative engagement and critical evaluation of mathematical models. Finally, by conceptual synthesis, these results were integrated and mapped across the TPACK, SAMR, and 4Cs frameworks to reveal and draw attention to convergences, divergences, and the importance of the mediating role of TPACK. This methodical analysis produced aggregated conclusions on the pedagogical benefits of digital mathematics resources, facilitating the development of an integrated instructional design philosophy in support of 21st-century mathematics education. The methodological process adopted in this study for the ILR is illustrated in Figure 1.

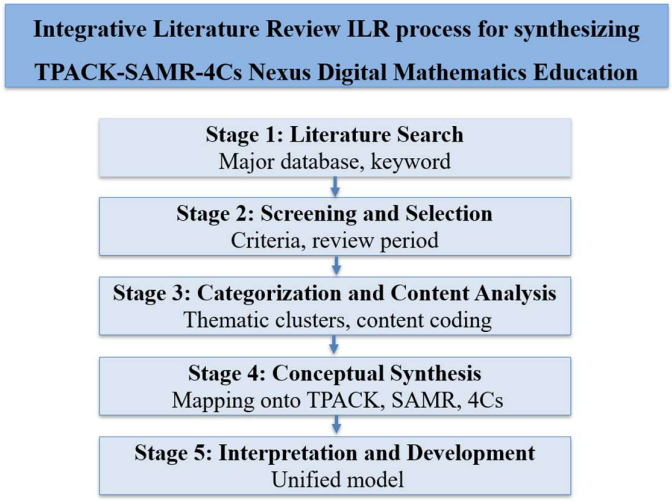

Figure 1: Graphical framework illustrating the Integrative Literature Review (ILR) process for synthesizing the TPACK–SAMR–4Cs nexus in digital mathematics education.

IV. RESULTS

For methodological transparency and analytic rigor, findings are presented in accordance with the systematic review procedures outlined in the methodology. A total of 23 reviewed studies (2010–present) that met all inclusion criteria were analyzed using a three-stage coding structure corresponding to: (a) the level of technology integration (SAMR), (b) the degree of teacher technological–pedagogical expertise (TPACK), and (c) the extent to which learning outcomes targeted 21st-century skills (4Cs). This coding framework provided a consistent foundation for identifying meaningful cross-study patterns.

This comprehensive investigation produced two key conclusions, which are shown separately in Tables 1 and 2. While Table 2 summarizes research showing that teachers' integrated TPACK is the crucial mediator enabling transformational (M/R-level) technology use, Table 1 illustrates how levels of technology integration within the SAMR model serve as strong indicators of 4Cs development.

4.1 Finding 1: SAMR as an indicator of 4Cs development

To present the first major finding clearly and systematically, the evidence related to the relationship between SAMR levels and 4Cs development was synthesized and organized into thematic categories. Table 1 provides a structured summary of these patterns, showing how different levels of technological integration contribute to varying degrees of higher-order skill development.

Table 1: Summary of systematic findings for SAMR to 4Cs development

SAMR Level	Key Findings from Systematic Review	Implications for 4Cs Development
Beyond Augmentation (A → M/R)	Substantial evidence shows that 4Cs development increases when technology integration surpasses the Augmentation level (Hamilton et al., 2016, pp. 433-441; Drugova et al., 2021, pp. 4923–4948)	Higher SAMR levels enable deeper engagement, inquiry, and reasoning.
Modification (M)	Use of Dynamic Mathematics Software (GeoGebra, Desmos) supports hypothesis testing, model evaluation, and critical questioning of mathematical relationships (Hoyles, 2018, pp. 209-228; Juandi et al., 2021, pp. 1-8).	Strong effect on Critical Thinking and Conceptual Understanding.
Redefinition (R)	Tasks that enable previously impossible learning experiences show the highest levels of Collaboration and Creativity, often supported by collaborative digital platforms (Ke, 2014, pp. 26-39)	Strong effect on Collaboration and Creativity; shifts focus from procedure → innovation.
Meta-analytic Evidence	Model-based learning, exploration, and simulations consistently improve achievement and conceptual reasoning (Cheung & Slavin, 2013, pp. 88-113; Steenbergen-Hu & Cooper, 2013, pp. 970-987)	Reinforces the need for exploratory problem-solving environments to build 4Cs holistically.

Content analysis confirmed that the development of 21st-century skills is related to the Task Transformation level (Drugova et al., 2021, pp. 4923–4948). Generalizable learning gains were found across studies when digital technologies were introduced beyond the Augmentation level, the level where a particular level of functional improvement does not drastically impact the core mathematical problem (Hamilton et al., 2016, pp. 433-441).

At the Modification (M) level, Dynamic Mathematics Software (DMS), such as GeoGebra, provides a platform for hypothesis testing, model evaluation, and exploration of complex mathematical relationships. The resulting environments moved student engagement away from procedural computation and toward analytical reasoning and conceptual inquiry (Hoyles, 2018, pp. 209-228; Juandi et al., 2021, pp. 1-8). Meta-analytic evidence also confirms that exploration and model-based tasks produce significant improvements in conceptual understanding and achievement (Cheung & Slavin, 2013, pp. 88-113; Steenbergen-Hu & Cooper, 2013, pp. 970-987).

At the Redefinition (R) stage, learning activities enhanced by technology enable possibilities that would otherwise be unattainable. Students worked well together and showed creative thinking. Using digital platforms, they were able to discuss, share ideas, and solve math problems together. Open-ended modeling tasks encouraged them to find new ways to represent and solve problems (Ke, 2014, pp. 26-39).

4.2 Finding 2: TPACK as a critical mediator for High-Level integration

The second main finding concerns how teachers' technological and pedagogical skills enable them to use digital tools in new ways. The studies reviewed indicate that TPACK is the main factor affecting SAMR-level outcomes. Table 2 shows how different parts of TPACK shape the depth and quality of technology use.

Table 2: Summary of systematic findings for TPACK to high-Level SAMR integration

TPACK Dimension	Key Findings from Systematic Review	Implications for SAMR & Pedagogical Practice
Integrated TPACK	Teachers with strong integrated TPACK (especially TPK + PCK) are the only ones capable of designing and implementing M/R-level tasks (Drijvers et al., 2010, pp. 213-234; Tondeur et al., 2017, pp. 555-575).	TPACK directly enables High-Level SAMR, leading to stronger 4Cs outcomes.
TPACK Deficit → S/A Levels	Limited TPACK results in technology being used only for substitution or minor enhancement, yielding low cognitive impact (Abbitt, 2011, pp. 281-300; Muslimin et al., 2023, pp. 1-15).	Explains why many classrooms remain stuck at S/A levels, even with abundant technology.
Content-Specific TPACK PD	The most effective professional development integrates technology with mathematical content and pedagogy rather than teaching tools in isolation (Polly & Orrill, 2012, pp. 1-32; Theodorio et al., 2024, pp. 1-18).	Professional development must target mathematics-specific TPACK, not tool training.
TPACK → SAMR → 4Cs Pathway	Evidence confirms a mediating chain: strong TPACK → M/R-Level tasks → 4Cs outcomes.	Supports the creation of Unified Instructional Design Principles for digital mathematics education.

A review of TPACK-related studies shows that when teachers combine technological, pedagogical, and content knowledge, this combination plays a key role in whether technology use reaches the transformative Modification (M) or Redefinition (R) stages of the SAMR model. Teachers with strong TPACK—especially those exhibiting well-developed Technological Pedagogical Knowledge (TPK)—designed pedagogically sound, technology-enhanced tasks that aligned with higher-order learning objectives (Drijvers et al., 2010, pp. 213-234; Tondeur et al., 2017, pp. 555-575).

However, limited TPACK consistently led to technology use at only the substitution or augmentation levels, with minimal improvement in cognitive benefits (Abbitt, 2011, pp. 281-300; Muslimin et al., 2023, pp. 1-15). These trends suggest that the implementation gap is not due to the availability of digital tools but rather to a lack of integrated technological–pedagogical reasoning. Consequently, content-driven professional development—where technology and pedagogy are fully embedded within mathematical content—is essential (Polly & Orrill, 2012, pp. 1-32; Theodorio et al., 2024, pp. 1-18).

4.3 Conceptual synthesis: Unified instructional design principles

Integrating findings across the TPACK, SAMR, and 4Cs frameworks led to the proposal of four unified instructional design principles for optimizing digital mathematics education. These principles explicitly align advanced technology use with the cultivation of 21st-century competencies, as shown in Table 3.

Table 3: Unified instructional design principles for digital mathematics education: a synthesis of TPACK, SAMR, and 21st-century skills (4Cs)

Principle	Framework Synthesis	Rationale and Supporting Evidence
1. Design for Transformation (M/R Target)	SAMR serves as the design goal, requiring learning tasks to reach Modification or Redefinition levels	Tasks must be sufficiently complex to necessitate the 4Cs, fostering higher-order reasoning beyond procedural fluency (Harskamp, 2014, pp. 383-392).
2. Prioritize Integrated TPACK Development	TPACK represents the teacher's essential capacity to implement technology effectively	Without integrated TPACK, technology use defaults to the less impactful A level, limiting opportunities for 4Cs development (Abar & Almeida, 2025, pp.1-8; Muslimin et al., 2023, pp. 1-15).
3. Foster Digital Authenticity	TPACK represents the teacher's essential capacity to implement technology effectively.	Digital tools should support open-ended modeling and problem-solving, enabling students to create and critically evaluate their own representations (Hoyles, 2018, pp. 209-228).
4. Structure for Digital Discourse	Directly targets Collaboration and Communication within shared digital environments	Learning tasks should require interactive digital workspaces where students articulate reasoning and negotiate collective solutions (Drijvers et al., 2010, pp. 213-234).

This systematic synthesis confirms that the transformative potential of digital tools in fostering 21st-century skills is directly proportional to the teacher's integrated TPACK and their intentional pedagogical design of learning experiences at the Modification and Redefinition levels of the SAMR model.

V. CONCLUSION AND DISCUSSION

This Integrative Literature Review (ILR) clarifies how the TPACK framework, the SAMR model, and 21st-century skills (4Cs) are interconnected in digital mathematics education. The synthesis of studies from 2015 to 2025 shows that simply having access to technology does not automatically develop the 4Cs. Instead, these skills grow when teachers use thoughtful teaching methods based on their professional expertise. In particular, the transformative potential of digital tools is most consistently realized when teachers enact robust, integrated TPACK to design and implement learning tasks at the Modification (M) and Redefinition (R) levels of SAMR. By integrating evidence across the reviewed literature, this study offers a coherent framework that helps bridge the gap between digital access and meaningful pedagogical transformation.

The study offers two primary contributions to the field. First, it establishes a unified, three-lens analytic model (TPACK–SAMR–4Cs) that provides a theoretical explanation for why transformational outcomes are most prevalent at the M/R levels. Second, it translates this theoretical synthesis into practical design principles that guide classroom practice, teacher professional development, and policy-level decisions. Several key insights emerge from this study. First, the implementation gap—particularly in contexts such as Thailand—stems from a TPACK deficit rather than a mere lack of digital infrastructure. Evidence suggests that many

educators remain at the Substitution and Augmentation levels, often due to limited Technological Pedagogical Knowledge (TPK) rather than a scarcity of resources (OEC, 2023). Addressing this requires professional development that is not only content-based but also intentionally utilizes the SAMR model to help teachers align technology with mathematical reasoning. Second, the Unified Instructional Design Principles provide actionable implications for policy, emphasizing M/R-level task design to encourage collaboration, creativity, and authentic problem-solving. Finally, as an ILR, this study is limited by its reliance on secondary data. Future research should employ longitudinal and experimental designs to empirically validate these Unified Principles and track the trajectory of teachers' TPACK–SAMR competencies and their subsequent impact on student outcomes. Such evidence will further strengthen the conceptual foundation provided here, driving the evolution of innovative, evidence-informed digital pedagogy in mathematics.

SUGGESTION

The established interplay between TPACK, SAMR, and the 4Cs, therefore, recommends two crucial steps for advancing digital mathematics education. First, policymakers in education need to redefine teacher professional development (PD) to more explicitly transition from basic tool training to content-specific, integrated TPACK development. This PD needs to be focused on the Unified Instructional Design Principles—specifically, developing learning tasks to intentionally target the Modification (M) and Redefinition (R) levels of the SAMR model—as an essential skill of all mathematics educators. Second, curriculum designers and school administrators must prioritize tasks that integrate Digital Discourse and Digital Authenticity. This is about moving away from substitution-level digital worksheets toward structured, open-ended modeling and collaborative problem-solving activities that require higher-order Critical Thinking and Communication skills. It is possible to successfully close the ongoing gap between technological access and real pedagogical change in the classroom by carefully incorporating these ideas into both practice and policy.

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The content, as well as the use of language in the article, is the responsibility of the author.

DEVELOPMENT OF ELECTRONIC BOARD GAME TO ENHANCE DIGITAL MEDIA LITERACY AMONG THE ELDERLY IN CHANTHABURI PROVINCE

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ABSTRACT

This research was an application of microcontroller technology in collaboration with board game mechanics by building interactions through light, color and sound. Gameplay mechanics were designed based on a random reward system in order to motivate learning. The players would get moving on the board when answering the questions correctly. There were also other various auxiliary components to increase challenge and interest throughout the game. These mechanics aimed at creating positive interactions and enhancing digital media literacy absorption among the elderly. The sample used in this research was a group of 30 elderly from Elderly School, Plap Phla subdistrict, Mueang district, Chanthaburi province gaining from simple random sampling. The research instruments included a set of an electronic board game, a digital media literacy test and a satisfaction questionnaire with 15 items. Statistics consisted of mean, standard deviation, percentage and statistical hypothesis testing (t-test). The results found that: 1) the quality of the electronic board game as a whole was at the excellence level ($\bar{x}$ = 4.84, SD = 0.93), 2) the elderly's digital media literacy test score after playing the game was higher than before playing the game with statistical significance at the .05 level, and 3) the elderly's satisfaction towards the electronic board game to enhancing digital media literacy was at the highest level ($\bar{x}$ = 4.53, SD = 0.55). The results of the study can be summarized that the electronic board game is an effective instrument to enhance digital media literacy for the elderly.

Keywords: Electronic board game, Elderly, Digital media literacy

I. INTRODUCTION

Thailand entered an aged society in 2022, by which the elderly aged 60 years and over were accounted for 18.3% of the total population (Uton, 2023, Online). Entering an aged society has an impact on the caregiver burden, health expenses and a decrease in the number of workforce. Therefore, the government needs to promote the elderly's health, self-reliance and participation. One of the popular ways is the usage of social media, such as Line and Facebook, to communicate and follow the news. Though the elderly can access to the online media well, their media literacy is still needed to develop. This is because data analysis and data authentication on social media require specific skills which decreased with age Rachpiboon (2021, pp. 67-68). The development of these skills will help the elderly live in the digital society safely and happily.

Research indicates that Thai elderly individuals continuously use digital media in their daily lives, primarily focusing on communication and receiving information through online channels such as Line, Facebook, and YouTube. However, the level of media literacy among this demographic remains moderate, and they often lack in-depth critical thinking skills; as a result, they are at risk of receiving inaccurate or false information. Personal factors including gender, education level, occupation, income, and technological experience all have a statistically significant impact on their digital media proficiency (Rueangyot, 2020, p. 74; Pakdeemualchon and Rattanasimakul (2022, pp. 21-24). Furthermore, empirical evidence shows that participatory activities, especially board games, play a crucial role in developing media literacy skills. These activities enhance comprehension, practical application, and motivation for continuous learning, serving as an effective strategy to reduce the risk of misinformation and promote overall media literacy among the elderly (Yingprathanporn et al., 2024, pp. 374-376; Piboonpanuwat et al., 2020, p. 174).

Currently, board games, which are games playing on boards with accessories, are used in education by designing them in consistent with the contents to create both enjoyment and knowledge acquisition. One of these games is an electronic board game that works in collaboration with a microcontroller that has the duty to control equipment such as LED bulb, push-button switch and dot matrix. Integration of microcontroller helps to increase enjoyable, exciting and novel playing formats, for example, digital output, score report and signals. These playing formats enhance players' planning skill, strategic thinking, problem solving and teamwork.

Therefore, the researchers developed an electronic board game to enhance digital media literacy among the elderly in Chanthaburi province to create happiness and enjoyment as well as to stimulate digital media literacy in order to make the elderly live happily with both physical and mental safety.

II. LITERATURE REVIEW

Previous studies demonstrated that Thai elderly people continuously accessed online media, especially LINE, Facebook, and YouTube (Rueangyot, 2020, p. 74). However, their media literacy was at a moderate level, reflecting the need to enhance analytical and media creation skills. Differences in gender and educational level were found to affect media literacy, with females and highly educated individuals often demonstrating better assessment and information access skills. Similarly, Pakdeemualchon and Rattanasimakul (2022, pp. 21–24) reported that career background, familiarity with technology, and frequency of use influenced Facebook usage and levels of media literacy. In addition, most elderly media use focused more on recreation and self-expression than on business purposes. When these findings are synthesized, they indicate that although the elderly have potential in media use, they still lack in-depth screening and critical evaluation skills. This highlights the importance of educational media design that promotes analytical thinking, content production, and continuous learning motivation. Previous research has also shown that board games can play a significant role in developing media and technology literacy among various target groups. Yingprathanporn et al. (2024, pp. 374–376) demonstrated that board games effectively transferred knowledge about cyber threats while enhancing both understanding and player satisfaction. This finding is consistent with Piboonpanuwat et al. (2020, p. 174), who found that applying the "Stop–Think–Ask–Do" concept alongside the role of wellness communicators improved data screening skills and reduced uncritical media consumption. Overall, this synthesis suggests that both board games and digital media have a significant role in enhancing media literacy, particularly for the elderly who face increasing challenges in a digital society.

The hypothesis of this research was the elderly who played the electronic board game would have the score of digital media literacy test after playing the game higher than before playing the game with statistical significance at the .05 level.

III. RESEARCH METHODOLOGY

This study was a Research and Development (Meesuwann, 2022, pp. 89-90) consisting of conceptual framework, scope of study, research instrument, data collection and data processing and analysis.

3.1 Conceptual Framework

The researchers had determined the conceptual framework of the study as shown in Figure 1 on development of electronic board game to enhance digital media literacy among the elderly in Chanthaburi province as follows:

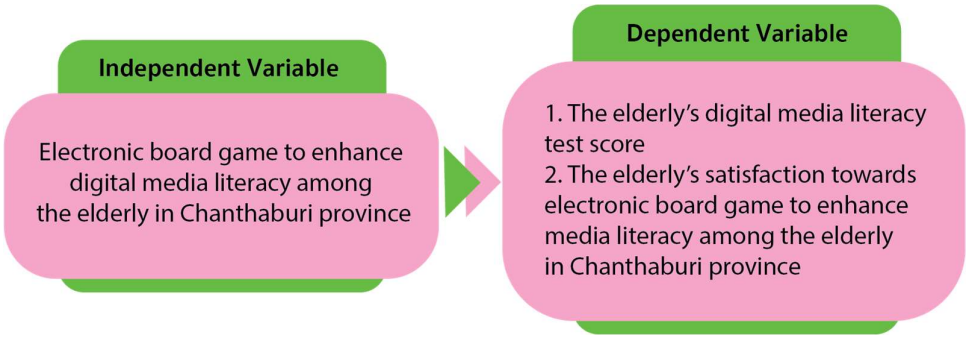

Figure 1: Conceptual Framework

3.2 Scope of Study

Scope of population and sample group: the population used in the research was 992 elderly in Chanthaburi province, and the sample used in the research was a group of 30 elderly from Elderly School, Plap Phla subdistrict, Muang district, Chanthaburi province gaining from simple random sampling, by which the sample size was determined according to the method of Chaiyong Promwong (Brahmawong, 2013, pp. 7-20).

Scope of variables used in the research: an independent variable was the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province, and dependent variables were the elderly's digital media literacy test score and the elderly's satisfaction towards the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province.

Scope of contents on the elderly's digital media literacy: Wuttirangsee (2016, pp. 96-102) mentioned four aspects including media literacy, understanding the contents, media analysis and evaluation, safe interaction and real life application. Assawatinna (2022, pp. 33-35) determined three aspects including assessment, analysis and media access. The researchers, therefore, synthesized these two concepts into four main aspects including data evaluation of correct news and fake news, security and privacy, digital competency, digital law and critical thinking.

3.3 Research Instrument

1. A set of an electronic board game to enhance digital media literacy among the elderly in Chathaburi province was passed the quality assessment by five experts. The instruments consisted of an electronic box, shown in Figure 2, used for random question cards and auxiliaries together with showing LED light and playing sound through a small speaker, a board of game, pieces and 80 question cards according to the question types including: green cards containing questions about correct news and fake news, red cards containing questions about security and privacy, blue cards containing questions about digital competency and yellow cards containing questions about digital law and critical thinking categorized by the contents, and three auxiliary cards including: friend helps friend, change the question card and check the answer then move one more space. The electronic box used microcontroller board Arduino Uno R3 to control 16-LED-ring display, 8 x 8 dot matrix to push the small speaker to play a melody and buttons for randomly selecting questions, auxiliaries and number of space.

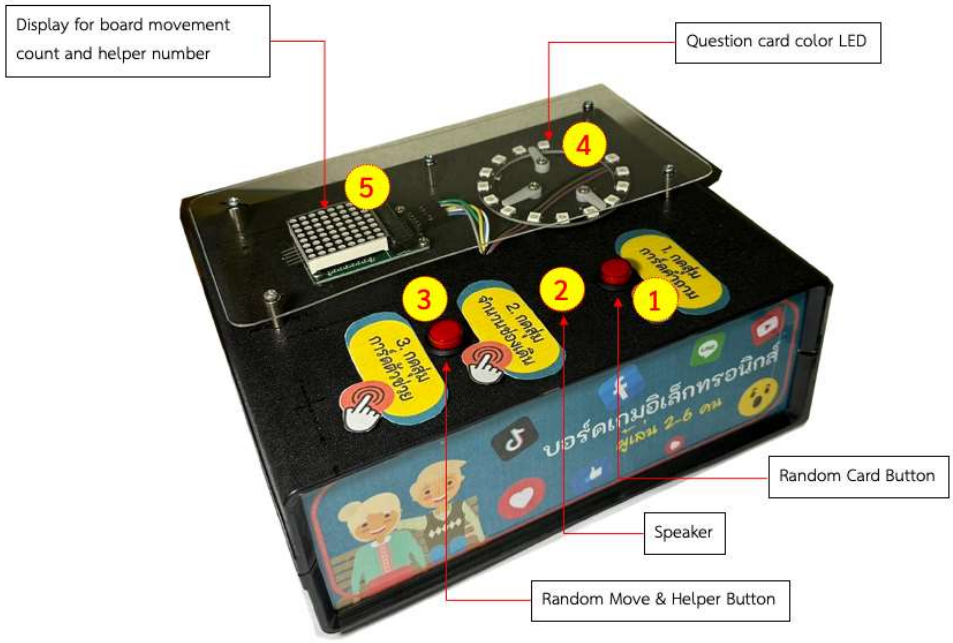

Figure 2: Electronic box

In Figure 3-5, playing method of board game started by having each player choose his own piece. The playing sequence would be repeated until every one had played. The first player pressed the button to randomly select the question card. If he randomly got a question card of any color, the next player had to turn up the card to read the question. If the player could not answer the question by himself, he could use his right to press the button to randomly choose the auxiliary card: ask his friend to help suggest the answer, randomly change the question or has the right to move one free space. In which the player could use one auxiliary per a moving cycle. The player who reached the finish line first would be the winner of that cycle.

2. A 20-item media literacy test with two multiple choices was evaluated its quality by five experts and found that Index of Item-Objective Congruence (IOC) was between 0.80-1.00.

3. A 15-question test of satisfaction towards the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province in the form of rating scale with five-level rating scale according to Likert (Likert scale) had Index of Item-Object Congruence (IOC) for measuring satisfaction behaviors between 0.80-1.00.

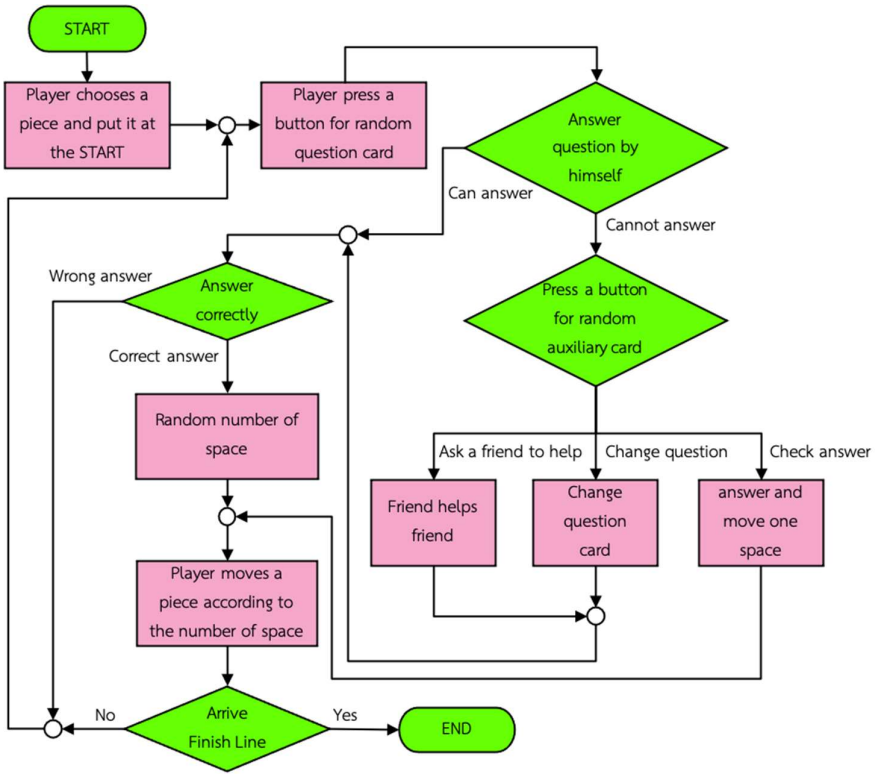

Figure 3: Playing method of electronic board game to enhance digital media literacy among the elderly in Chanthaburi province

Figure 4: Examples of the back side of four-color question cards (left pictures) and the front of the auxiliary cards (right pictures)

Figure 5: A board of the electronic board game

3.4 Data Collection

The sample group of the elderly voluntarily participated in the trial. The researchers explained the operation details and distributed a test on media literacy before using the electronic board game to the elderly who were able to read and write to do the test by themselves. For those who were unable to read and write, the research assistant would read the questions to them and record their answers. The test took about 20 minutes, then collected. The researchers introduced the equipment and playing method as well as divided the players into two-six players each group. The research assistant acted as a game master to facilitate and determine the playing order. After playing, the sample group did the test again to check their scores. Then the results of their pre-test and post-test were comparatively analyzed and evaluated their satisfaction towards playing the electronic board game.

3.5 Data Analysis

Data analysis consisted of quality and satisfaction assessment of the electronic board game by using mean, standard deviation and comparison of pre-and post-digital media literacy test scores by using t-test for dependent samples.

This research received human research ethics approval from Rambhai Barni Rajabhat University, no. IRB-35/2567.

IV. RESULTS

From this research, the researchers summarized the data analysis results with the details as follows:

4.1 The development result and quality examination of one set of the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province passed the quality assessment from five experts at the excellent level ($\bar{x}$ = 4.84, SD = 0.93).

Table 1: The quality assessment result of electronic board game to enhance digital media literacy among the elderly in Chanthaburi province

Evaluation list	$\bar{x}$	SD	Level of quality
1. Clarity of color and light of numbers.	5.00	0.00	Excellent
2. Use beautiful colors and attract attention.	5.00	0.00	Excellent
3. Clarity of instructions in the board game playing rule manual.	5.00	0.00	Excellent
4. Convenience in using board game equipment.	5.00	0.00	Excellent
5. Accuracy of content.	4.80	0.45	Excellent
6. The questions on the cards are appropriate for game players.	4.80	0.45	Excellent
7. Clarity of pictures on the cards.	4.80	0.45	Excellent
8. Size of information on the cards can be seen clearly.	4.80	0.45	Excellent
9. Appropriateness of time spending on playing board game.	4.80	0.45	Excellent
10. Appropriateness of playing method.	4.60	0.55	Excellent
11. Conform to application of board game to enhance digital media literacy among the elderly.	4.60	0.55	Excellent
Total	**4.84**	**0.93**	Excellent

From Table 1, data analysis results of quality assessment of the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province by five experts as a whole was at the excellent level ($\bar{x}$ = 4.84, SD = 0.93). When determined by item found that the first four items had the highest mean including: item 1. Clarity of color and light of number, item 2. Use beautiful colors and attract attention, item 3. Clarity of instructions in the board game playing rule manual and item 4. Convenience in using board game equipment ($\bar{x}$ = 5.00, SD = 0.00).

4.2 Comparison results of digital media literacy test scores before and after playing the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province

Comparison results of test scores before and after playing the electronic board game by comparing the pre-playing score with the post-playing score using t-test had statistical significance at the .05 level as illustrated in Table 2.

Table 2: Comparison results of digital media literacy test scores before and after playing the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province

Assessment	Number (people)	Full Score	$\bar{x}$	SD	t	Sig
Before playing	30	20	15.60	1.48	10.14*	.000
After playing	30	20	17.63	1.50		

* Statistical significance at the .05 level

From Table 2, it was found that test statistic value (t-test) was 10.14. Mean of pre-playing score was 15.60 and standard deviation was 1.48. Mean of post-playing score was 17.63 and standard deviation was 1.50. In conclusion, the result of the elderly's digital media literacy test after playing board game was higher than before playing with statistical significance at the .05 level.

4.3 The results of the elderly's satisfaction towards the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province

Table 3: The results of the elderly's satisfaction towards the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province

Evaluation list	$\bar{x}$	SD	Level of quality
1. Overview towards electronic board game.	4.70	0.47	Highest
2. Enhance digital media literacy among the elderly.	4.67	0.55	Highest
3. The time spent playing is appropriate.	4.63	0.49	Highest
4. The pictures are clear.	4.60	0.50	Highest
5. Have fun and enjoyment.	4.60	0.56	Highest
6. Interaction between the players and the electronic board game.	4.60	0.56	Highest
7. The electronic board game is interesting, exciting and challenging.	4.57	0.50	Highest
8. Fonts are easy to read and clear.	4.53	0.57	Highest
9. The language used in the manual is easy to understand.	4.50	0.57	High
10. Playing method is not complicated.	4.50	0.51	High
11. Improve better understanding of digital media literacy.	4.50	0.51	High
12. The game has colors, lights and sounds.	4.47	0.57	High
13. Rules, regulations and conditions are easy to understand.	4.43	0.63	High
14. Have a clear objective.	4.40	0.62	High
15. Scoring electronic board game playing.	4.30	0.65	High
Total	**4.53**	**0.55**	**Highest**

The analysis results of the elderly's satisfaction towards the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province illustrated in Table 3 found that the data analysis results of the elderly's satisfaction towards the electronic board game to enhance digital media literacy among the elderly in Chanthaburi province as a whole was at the highest level ($\bar{x}$ = 4.53, SD = 0.55). When determined by item found that the first three items with the highest mean included: Item 1. Overview towards electronic board game ($\bar{x}$ = 4.70, SD = 0.47), followed by Item 2. Enhance digital media literacy among the elderly ($\bar{x}$ = 4.67, SD = 0.55) and Item 3. The time spent playing is appropriate ($\bar{x}$= 4.63, SD = 0.49).

V. CONCLUSION AND DISCUSSION

The research results found that the quality of the electronic board game as a whole was at the excellent level ($\bar{x}$ = 4.84, SD = 0.93). The test score of the elderly's digital media literacy after playing the game was higher than before playing the game with statistical significance at the .05 level. In addition, the elderly's satisfaction towards the electronic board game to enhance digital media literacy was at the highest level ($\bar{x}$ = 4.53 , SD= 0.55). These demonstrated that the electronic board game was an effective instrument in enhancing the elderly's digital media literacy.

The results could be discussed as follows : (1) The overall quality of the electronic board game was at the excellent level. This resulted from the game design and development process, which involved assessments by five experts in computer program development, gerontology, public health, measurement and evaluation, and educational technology, followed by improvements based on their suggestions (e.g., enlarging button size, adding a display device protection panel for safety and damage prevention). The playing method featured a clear structure encouraging all players' participation, with key elements including random processes, question-answering, and auxiliaries that made the game challenging and fun, promoting participation, critical thinking, and decision-making across stages via a balance of skill and luck suitable for group activities or education. Research on educational board games shows that random mechanisms (e.g., dice rolling, random cards) enhance challenge and enjoyment (Sousa et al., 2023, p. 5), increasing participation, collaboration, communication, and creative thinking in class. Sato et al. (2020, pp. 13-14) categorized random prize mechanisms that stimulated players' motivation, excitement and satisfaction besides random mechanisms. Other auxiliaries such as easy-to-grip pieces, level skipping on the board or expressing opinion together also helped enhance the playing quality of those elements and support critical thinking, collaboration and comprehensive life skills development. Smith (2024, p. 10) found that usage of a role-playing card and a special score system helped create motivation and casual learning environment. Kinne (2021, Online) insisted that beautiful and actually tangible pieces increased enjoyment and playing experiences. Therefore, random mechanisms and auxiliary elements play a crucial role in enhancing both enjoyment and learning outcomes in board games. (2) The integration of media literacy content into the electronic board game resulted in a statistically significant improvement in elderly participants' media literacy scores. This finding highlights the potential of game-based media to effectively convey applicable real-life knowledge through innovative instructional design that strategically integrates gameplay mechanics with learning objectives, thereby fostering an engaging and participatory learning environment. The present result is consistent with prior studies. Tsai et al. (2024, p. 212) reported that board game–based interventions significantly enhanced elderly individuals' knowledge and osteoporosis-preventive behaviors, while Moontienthong et al. (2023, pp. 280–281) demonstrated that board games stimulate cognitive activity and support cognitive development among older adults. These findings collectively suggest that the integration of play mechanisms with learning acquisition represents an effective form of innovative design that promotes enjoyment and participatory learning. Consequently, the electronic board game can be considered a valuable educational tool for skill development and for enhancing the quality of life of elderly populations. (3) Elderly participants reported the highest satisfaction with the electronic board game.

This stems from mechanism designs emphasizing fun, participation, and fairness, which create efficient learning experiences; key elements like piece selection, random questions, and auxiliary cards reduce pressure while maintaining challenge and balance, fostering motivation and continued play. The results align with Guardabassi et al. (2024, p. 4), who reported that increasing game difficulty raised elderly satisfaction significantly, and Chen and Tsai (2022, p. 10), who found board games strengthen confidence, communication, and reduce loneliness sustainably. These trends highlight the electronic board game's potential not only for entertainment but also for promoting health and comprehensive learning among the elderly.

SUGGESTION

1) Suggestions for the application of research results: The electronic board game developed to enhance digital media literacy among the elderly in Chanthaburi Province was found to effectively improve participants' knowledge and their ability to appropriately apply this knowledge in daily life. To further increase the effectiveness of the activities, it is recommended that the activity design incorporate regular rotation of group members. Such rotation would provide greater opportunities for knowledge sharing, enhance social interaction among the elderly, and promote collaborative communication skills. Additionally, facilitators should encourage active participation and discussion during gameplay to maximize learning outcomes and engagement. 2) Suggestions for future research should explore the effectiveness of the electronic board game among larger and more diverse samples of elderly participants across different geographical areas in order to enhance the generalizability of the findings. Further studies may also examine the long-term impact of the game on digital media literacy and actual technology usage behaviors in daily life. Moreover, comparative studies involving different types of digital or non-digital learning media could provide deeper insights into the most effective approaches for promoting digital media literacy among the elderly.

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ENHANCING GRADUATE INSTRUCTION THROUGH THE ESSENCE PROCESS IN A PHILOSOPHY AND THEORY OF EDUCATION COURSE

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ABSTRACT

This classroom action research addressed a persistent research gap concerning the limited availability of structured instructional processes that effectively translate philosophical and educational theory into practice at the graduate level by exploring the use of the ESSENCE instructional process—a seven-step framework designed to bridge theory and practice—in a graduate-level Philosophy and Theory of Education course. Instruction was delivered online over four consecutive weeks through synchronous sessions. The study aimed to (1) examine learning achievement following the intervention, (2) assess graduate students' ability to design an Integrated Learning Unit synthesizing philosophical and educational theories, contemplative education, experiential learning theory, participatory action research (CPAR), and the sufficiency economy philosophy, and (3) analyze the quality of students' reflective thinking regarding learning and self-change. Participants were 11 graduate students—all full-time university lecturers from non-education fields (4 doctoral, 7 master's). The ESSENCE-based intervention comprised four lesson plans. Research instruments included an achievement test (Cronbach's α = .86), a performance assessment rubric, and a reflective-journal protocol. Quantitative data were analyzed using mean and standard deviation; qualitative data were examined through content analysis. Results indicated gains in learning achievement, with mean scores increasing from 16.20 to 23.11 out of 34. Graduate students demonstrated the ability to translate theory into practice through integrated learning unit design products ($\bar{x}$ = 25.05 out of 30), reflecting creative synthesis of conceptual frameworks with instructional planning. Reflective-journal analysis revealed a shift from externally oriented practice toward internalized professional growth, including increased attention to deep listening and deliberate mental cultivation. Overall, the findings highlight the distinctive contribution of the ESSENCE process in supporting theory-in-action and transformative professional learning by integrating structured public reasoning, collaborative design, and reflective refinement in graduate instruction.

keywords: ESSENCE process, Graduate instruction, Philosophy and theory of education, Integrated learning unit, Reflective thinking

I. INTRODUCTION

Graduate education in philosophy of education is expected to cultivate the capacity to connect educational aims with action—engaging in public reasoning about purposes, followed by designing for learning and social value. However, within graduate-level philosophy and theory of education courses, instructional practices often remain predominantly concept-driven and discussion-oriented, offering limited structured support for translating philosophical and educational theories into coherent, practice-based instructional designs. This gap is particularly salient for graduate learners from non-education backgrounds, who may demonstrate strong conceptual understanding yet face challenges in integrating theory, instructional design, and reflective professional development in authentic learning contexts. Globally, the Organisation for Economic Co-operation and Development (OECD, 2024, pp. 7–9) reports that adult upskilling systems must respond to rapid transitions in Artificial Intelligence (AI) and green technologies while removing participation barriers such as time, cost, and low perceived need (e.g., "no need," "too busy," "too expensive"). The United Nations Educational, Scientific and Cultural Organization (UNESCO, 2023, pp. 15–16) cautions that technology is a means—not an end—and should be used only where it supports equitable, evidence-informed learning, with attention to costs and context. In Thailand, the National Economic and Social Development Council (NESDC, 2023, pp. 4–5) emphasizes a high-capability, lifelong-learning workforce as a national milestone for opportunity and justice in its 13th National Economic and Social Development Plan (2023–2027). Complementing this, the Office of the Education Council (OEC, 2023, pp. 220–221) reports sustained public commitment—about 14.7% of the FY2021 national budget and 2.9% of GDP—paired with multilateral partnerships for curriculum, teacher development, and equity. These signals frame the present study's focus on a structured theory-to-practice routine for graduate instruction.

A growing body of scholarship identifies structured routines that help learners move from "theory talk" to "theory-in-action." Recent research on formative assessment demonstrates that frequent, criterion-referenced feedback supports learning improvement over time by enabling learners to use feedback for instructional adjustment and self-regulation (Carney et al., 2022, pp. 1–3). Experiential Learning Theory (ELT) proposes a process logic—experience → reflection → conceptualization → experimentation—that guides inquiry toward application in higher education and adult learning contexts (Kolb, 2015, pp. xxiii–xxiv). Critical Participatory Action Research (CPAR) positions pedagogy as a practice-changing practice enacted through public, reason-giving deliberation, offering a disciplined structure for improvement in and on practice (Kemmis et al., 2014, p. 30). Contemplative education further contributes to this transition by cultivating inner awareness, ethical discernment, and presence—capacities essential for meaningful application of theory in complex, real-world contexts (Zajonc, 2013, pp. 83–84). These frameworks consolidate literature across CPAR, ELT, and contemplative sources, where seminar reasoning is made public, criteria are explicit, and design work is iteratively tested.

This article introduces and examines the ESSENCE process—a seven-step instructional framework developed to address a persistent gap in graduate education: the absence of a structured pathway for translating philosophical and educational theory into coherent, practice-based design. Originally implemented in a graduate-level Philosophy and Theory of Education course, ESSENCE was designed to foster analytical thinking, collaborative inquiry, and reflective growth within a challenging yet safe intellectual space. The process comprises seven sequenced steps: (1) Engage— activate presence and curiosity through reflective or creative tasks presence; (2) Socratize—deepen inquiry through structured Socratic dialogue; (3) Search—investigate key questions and synthesize findings; (4) Examine—present, critique, and build meaning through dialogue; (5) Network—collaborate to connect diverse perspectives; (6) Conceptualize—build integrative frameworks linking theory and practice; and (7) Evolve—reflect to deepen insight and guide growth. The instructional design emphasized analytic rigor through achievement criteria and product-based outputs; formative mechanisms such as rubrics and peer feedback; and reflective practice via guided journals. These components align with Critical Participatory Action Research's improvement orientation and Experiential Learning Theory's sequencing from experience to application (Kemmis et al., 2014, p. 30; Kolb, 2015, pp. xxiii–xxiv), and collectively support learners in progressing from conceptual understanding (KNOW), through integrative application (BE), toward reflective transformation (TRANSFORM).

Accordingly, this study examines whether instruction through the ESSENCE process enhances learning achievement, supports the design of Integrated Learning Units that coherently synthesize philosophical and educational theories with contemplative education and the sufficiency economy philosophy, and deepens reflective thinking indicative of self-change. Contemplative education emphasizes inner awareness, ethical discernment, and presence as foundations for meaningful learning and transformation (Zajonc, 2013, pp. 83–84). The sufficiency economy philosophy, rooted in Thailand's development context and increasingly recognized in global discourse, promotes moderation, reasonableness, and resilience as guiding principles for sustainable decision-making and personal growth (United Nations Development Programme [UNDP], 2007, pp. xv–xvi; UNDP, 2024, pp. 1–3; UNESCO, 2012, pp. 43–45). To examine these outcomes, the study employs four ESSENCE-based lesson plans, a pre- and post-instruction achievement test, an analytic product rubric, and weekly reflective journals. These instruments aim to clarify how structured reasoning, collaborative design, and reflective refinement can translate theory into action within graduate-level instruction and inform broader educational practice.

II. LITERATURE REVIEW

A growing body of scholarship identifies structured instructional routines that help graduate learners move from "theory talk" to "theory-in-action." Recent research on formative assessment demonstrates that frequent, criterion-referenced feedback and instructional adjustment support learning improvement and self-regulated learning in higher education contexts (Carney et al., 2022, pp. 1–3). The theory of Experiential Learning proposes a process logic—experience → reflection → conceptualization → experimentation—that guides inquiry toward application in higher education and adult learning contexts (Kolb, 2015, pp. xxiii–xxiv). Sociocultural theory emphasizes the power of structured collaboration: assisted

performance within the zone of proximal development enables learners to move from current to potential functioning through guided support (Vygotsky, 1978, pp. 89–90), while classic tutoring research describes scaffolding as graduated, contingent assistance that allows learners to complete tasks beyond their unaided capacity (Wood et al., 1976, p. 90). In parallel, structured and semi-structured reflection—such as guided journals, debriefs, and facilitated small-group dialogue—is reported to enhance learners' understanding of reflection and reflective capacity in university settings (Phenwan, 2024, pp. 5–7). The theory of Andragogy, which emphasizes self-direction, experience-based inquiry, and problem-centered tasks, aligns with the needs of adult learners, including university lecturers (Knowles et al., 2020, pp. 4–6). Contemplative education further contributes to this transition by cultivating inner awareness, ethical discernment, and presence—capacities essential for meaningful application of theory in complex, real-world contexts (Zajonc, 2013, pp. 83–84). The sufficiency economy philosophy, rooted in Thailand's development context and increasingly recognized in global discourse, promotes moderation, reasonableness, and resilience as guiding principles for sustainable decision-making and personal growth (UNDP, 2007, pp. xv–xvi; UNDP, 2024, pp. 1–3; UNESCO, 2012, pp. 43–45). Taken together, these strands of scholarship highlight key mechanisms—feedback, experiential sequencing, collaborative support, reflective practice, and adult learning principles—that facilitate the translation of theory into practice; however, they are often addressed as discrete approaches rather than integrated within a coherent, multi-step instructional framework. This limitation is particularly salient in graduate-level philosophy and theory of education, where learners are expected not only to understand complex theoretical perspectives but also to enact them through instructional design and reflective professional development. In response to this gap, the ESSENCE instructional process is conceptualized as an integrative framework that synthesizes these theoretical traditions into a structured routine oriented toward transformative learning and professional growth.

Guided by this literature, the study is grounded in the proposition that a structured, multi-step routine like the ESSENCE process may enhance graduate learning in three key areas: (a) improving learning achievement, (b) strengthening the translation of philosophical and educational theory into integrated design products, and (c) deepening reflective thinking indicative of professional growth. These theoretical foundations align with specific stages of the ESSENCE process—for example, Socratic dialogue reflects CPAR's public reasoning (Kemmis et al., 2014, p. 30), while sequenced experiential tasks mirror ELT's learning cycle (Kolb, 2015, pp. xxiii–xxiv). Frequent, criterion-referenced feedback and instructional adjustment support formative assessment by enabling learning improvement and self-regulation over time (Carney et al., 2022, pp. 1–3), and assisted performance and scaffolding correspond to collaborative inquiry and peer support (Vygotsky, 1978, pp. 89–90; Wood et al., 1976, p. 90). Structured reflection practices are embedded through guided journals and debriefs (Phenwan, 2024, pp. 5–7), while adult learning principles from Andragogy inform the design of self-directed, problem-centered tasks (Knowles et al., 2020, pp. 4–6). Finally, contemplative education and the sufficiency economy philosophy provide ethical and reflective dimensions that reinforce the process's emphasis on personal transformation and sustainable learning (Zajonc, 2013, pp. 83–84; UNDP, 2007, pp. xv–xvi; UNDP, 2024, pp. 1–3; UNESCO, 2012, pp. 43–45).

III. RESEARCH METHODOLOGY

In this research design, the study employed a classroom action research approach grounded in the principles of Critical Participatory Action Research (CPAR) to examine the outcomes of the ESSENCE instructional process in a graduate Philosophy and Theory of Education course. The ESSENCE process served as the central instructional and inquiry framework guiding the action research cycles, ensuring alignment between the research objectives, instructional design, and reflective practice. Consistent with CPAR, inquiry was treated as a practice-changing practice enacted through public, reason-giving deliberation and iterative spirals of planning, acting/observing, reflecting, and replanning (Kemmis et al., 2014, pp. 19–21, 30).

For the conceptual framework, this study is guided by nine foundational educational theories that were selected to inform both the design and implementation of the ESSENCE instructional process. These theoretical bases support the seven structured phases—Engage, Socratize, Search, Examine, Network, Conceptualize, and Evolve—and clarify how abstract educational theory is operationalized into instructional practice. Together, the theories and ESSENCE phases form a coherent structure that explains how the instructional process fosters three analytically distinct but related outcomes: learning achievement, integrated learning unit (ILU) design quality, and reflective thinking. Figure 1 presents the connections among the theoretical foundations, the independent variable (ESSENCE instructional process), and the three corresponding dependent variables examined in this study.

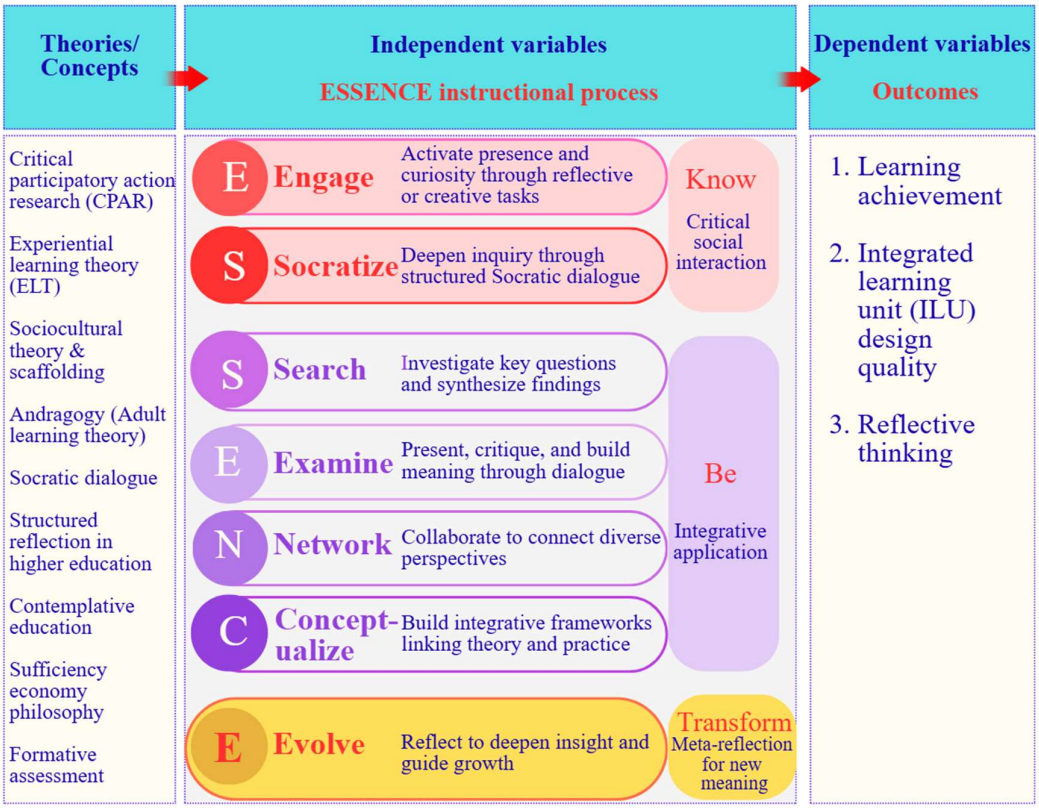

Figure 1: Conceptual framework linking foundational theories to the ESSENCE instructional process and outcomes

The study population comprised 11 full-time university lecturers from non-education fields who were enrolled in a graduate Philosophy and Theory of Education course in Semester 1, Academic Year 2025 (four doctoral, seven master's). All participants were included in the study. Instruction was delivered fully online across four consecutive weeks via Google Meet, with synchronous sessions supported by Padlet. During the final presentation phase, learners presented their Integrated Learning Units (ILUs) in a hybrid format: one co-instructor—responsible for a separate module on educational quality assurance—attended the in-person session, while the researcher participated remotely from another province. All participants provided informed consent prior to data collection.

Instructional instruments consisted of four ESSENCE-based online lesson plans, each explicitly aligned with the seven-step ESSENCE instructional process. The four lesson plans were implemented sequentially as follows: (1) Lesson Plan 1: Foundations of Philosophical Inquiry and Public Reasoning through the ESSENCE Process; (2) Lesson Plan 2: Educational Philosophy, Theory, and Policy Analysis through the ESSENCE Process; (3) Lesson Plan 3: Integrative Learning Unit Design through the ESSENCE Process; and (4) Lesson Plan 4: Reflective Integration and Professional Development through the ESSENCE Process. Each lesson plan was implemented in a continuous 6-hour session (3-hour morning + 3-hour afternoon, with a 1-hour lunch break). The lesson plans incorporated philosophical content and structured activities aligned with contemplative education principles—such as guided inquiry, ethical discernment, and inner awareness (Zajonc, 2013, pp. 83–84). In addition, the design of the Integrated Learning Unit (ILU) required participants to synthesize educational theory with the sufficiency economy philosophy, emphasizing moderation, reasonableness, and resilience in instructional decisions (UNDP, 2007, pp. xv–xvi; UNDP, 2024, pp. 1–3; UNESCO, 2012, pp. 43–45). Data-collection instruments included three complementary tools: (a) a four-option multiple-choice achievement test administered before and after the intervention, (b) an analytic rubric to assess the group product—an Integrated Learning Unit (ILU), with criteria aligned to intended learning outcomes and quality levels described along a continuum to support formative feedback and self-assessment (Brookhart, 2013, pp. 6–7), and (c) a qualitative recording instrument comprising a weekly reflective journal protocol (via Padlet) collected throughout the four-week intervention.

For learning support (Non-Graded), plan-specific formative quizzes provided rapid feedback and diagnostic insight. Their use followed principles indicating that frequent, criterion-referenced feedback and instructional adjustment support learning improvement and self-regulated learning over time (Carney et al., 2022, pp. 1–3). These quizzes were not included in summative scoring but served to reinforce conceptual understanding and support instructional decision-making throughout the intervention. To ensure instructional validity and contextual relevance, all lesson plans and the ESSENCE instructional process were reviewed by three doctoral-level experts specializing in education theory, curriculum and instruction, and educational measurement and research. Six domains were evaluated using a five-level scale (5 = excellent to 1 = needs improvement), with all domain means exceeding the preset criterion of 3.50. These domains included: (1) alignment and coherence, (2) target group appropriateness, (3) ESSENCE process quality, (4) instructional effectiveness, (5) unit-specific design quality, and (6) online delivery suitability. These dimensions reflect critical aspects of graduate-level instructional design, including philosophical integration, contemplative learning, and responsiveness

to learner diversity. In addition, the product-assessment rubric underwent expert review for content validity using the Index of Item–Objective Congruence (IOC; $+1/0/-1$) and a four-level rating of descriptor clarity. Overall properties considered included validity, reliability, feasibility, and fairness (Brookhart, 2013, pp. 6–7).

To ensure instructional validity and contextual relevance, the ESSENCE instructional process and all associated lesson plans were reviewed by three doctoral-level experts specializing in education theory, curriculum and instruction, and educational measurement and research. Six domains were evaluated using a five-level scale (5 = excellent to 1 = needs improvement), with all domain means exceeding the preset criterion of 3.50. These domains included: (1) alignment and coherence, (2) target group appropriateness, (3) ESSENCE process quality, (4) instructional effectiveness, (5) unit-specific design quality, and (6) online delivery suitability. Together, these domains capture key dimensions of graduate-level instructional design, including philosophical integration, contemplative learning, and responsiveness to learner diversity. In addition, the product-assessment rubric underwent expert review for content validity using the Index of Item–Objective Congruence (IOC; +1/0/–1) and a structured four-level rating of descriptor clarity. Overall properties considered included validity, reliability, feasibility, and fairness (Brookhart, 2013, pp. 6–7).

Achievement test initially developed as a 45-item draft was reviewed by three experts; all items met IOC $\geq .50$ (range .67–1.00). To guard against chance agreement, retention decisions referenced binomial-based critical values for Lawshe-type content validation (Ayre & Scally, 2014, pp. 79–81). A pilot try-out was then conducted with 29 in-service teachers enrolled in the same program and semester as the study group, but assigned to a different classroom section. Retention criteria were $p = .20–.80$ and $r \geq .20$, resulting in a 34-item operational achievement test. The final test produced Cronbach's $\alpha = .858$. In addition, across the four lesson plans, a set of 25 formative quiz items was reviewed by four doctoral-level experts—two specializing in philosophy of education, one in curriculum and instruction, and one in educational measurement and research. All items achieved an Index of Item–Objective Congruence (IOC) greater than .50 and were revised prior to administration (Ayre & Scally, 2014, pp. 79–81).

In data collection, three sequential phases were implemented during Semester 1, Academic Year 2025: (1) Pre-intervention, which included orientation and a pretest; (2) During intervention, which involved four ESSENCE-based lessons with weekly reflective journals and Week 5 Integrated Learning Unit (ILU) presentations used for formative feedback; and (3) Post-intervention, which comprised a post-test and submission of revised ILUs for summative assessment. All ILUs were scored by the researcher using the analytic rubric. To examine scoring consistency, one external expert (Ph.D.; instructor of the same course) co-rated two of the five group products. Agreement was high: Group 1 = 27.50 vs. 27.50; Group 2 = 26.00 vs. 25.50 (same performance level). The remaining three group products were rated by the researcher. Reflective journals invited participants to examine how contemplative education and the sufficiency economy philosophy informed their instructional design and personal growth. Contemplative education emphasizes inner awareness, ethical discernment, and presence as foundations for meaningful learning and transformation (Zajonc, 2013, pp. 83–84). The sufficiency economy philosophy promotes moderation, reasonableness, and resilience as guiding principles for sustainable decision-making and self-development (UNDP, 2007, pp.

xv–xvi; UNDP, 2024, pp. 1–3; UNESCO, 2012, pp. 43–45). These dimensions were explicitly embedded in the reflective journal prompts. Informed consent was obtained, and identifying details were removed from reported excerpts in accordance with institutional expectations.

For data analysis, reflective journals were examined using a six-phase thematic analysis with trustworthiness strategies—auditability, credibility, and dependability—to allow readers to trace how codes and themes were produced (Nowell et al., 2017, p. 3). For content-analytic staging, the process followed four analytic phases—decontextualisation, recontextualisation, categorisation, and compilation—used to guide interpretation (Bengtsson, 2016, p. 9). To enhance credibility, the draft analytic descriptions and interpretations were returned to all participants for verification (Nowell et al., 2017, p. 3). Learning achievement was analyzed using pre- and post-test scores summarized by Mean ($\bar{x}$) and Standard Deviation (SD, which are appropriate for classroom action research with a small sample size where the emphasis is on descriptive trends rather than statistical generalization. Application of knowledge was evaluated through Integrated Learning Unit (ILU) quality using the analytic rubric (Brookhart, 2013, pp. 6–7).

IV. RESULTS

From the analysis of data collected from the sample—11 graduate students—the research results can be summarized as follows.

1. Learning achievement after instruction using the ESSENCE process

The learning achievement of 9 graduate students (excluding one student who did not complete the pretest and another student who was absent during the posttest) is shown in Table 1.

Table 1: Learning achievement scores before and after instruction through the ESSENCE process

Test	Full score	Number of students	$\bar{x}$	%	SD
Pre-test	34	9	16.20	47.65	5.29
Post-test	34	9	23.11	67.97	5.38

From Table 1, the posttest mean score ($\bar{x}$ = 23.11) is clearly higher than the pretest means score ($\bar{x}$ = 16.20), indicating that the ESSENCE process can improve learners' learning achievement.

From Table 1, the posttest mean score ($\bar{x}$ = 23.11) is higher than the pretest mean score ($\bar{x}$ = 16.20). The percentage of correct responses increased from 47.65% to 67.97%, indicating an improvement in learning achievement among the graduate students following instruction using the ESSENCE process.

2. Ability to design an Integrated Learning Unit aligned with philosophical and educational theory, contemplative education, and the sufficiency economy philosophy

The researcher assessed the group product, Integrated Learning Unit (ILU) design, using an analytic rubric with a full score of 30 points. The quality levels were defined as follows: Excellent (27–30 points), Good (23–26 points), Fair (19–22 points), and Needs Improvement (below 19 points). The results are presented in Table 2.

Table 2: Assessment results for the quality of graduate students' group work: "Integrated Learning Unit Design"

Group	Score received (30 points)	Quality level
1	26.00	Good
2	27.50	Excellent
3	24.00	Good
4	24.00	Good
5	23.75	Good
Overall mean ($\bar{x}$)	25.05	Good
Standard deviation (SD)	1.64	–

From Table 2, the graduate students' group products achieved a mean score of 25.05 points, corresponding to the Good quality level. The results indicate that the groups were able to design Integrated Learning Units that aligned philosophical and educational theory, contemplative education, and the sufficiency economy philosophy as specified in the assessment rubric.

3. Quality of reflection on learning and self-change

From the qualitative content analysis of reflective journals voluntarily recorded by graduate students over four weeks (non-graded), 10 out of 11 graduate students regularly participated in reflection activities. Absences were non-repeating and did not substantially affect overall data coverage. Numbers in parentheses indicate the number of respondents for each item, with individual participants potentially contributing to multiple categories. The results are presented in Tables 3–5.

Table 3: Initial reflections after class

Category	Week 1	Week 2	Week 3	Week 4
Overall feelings	Enthusiastic (5), Fun (2), Meaningful (1)	Opened perspectives (2), Learned more (2), Fun (1), Excited (1)	Fun (2), Relaxed (1), Alert (1), Impressed (1), Able to develop oneself (1)	Calm/still/deep (3), Gained knowledge/ developed (3), Satisfied (1), Self-review (1)
Impressive activities	Philosophical questioning (7), Information searching (1)	Designing a dream school via Canva (2), Debate (2), Group work/discussion (2)	Theory presentation (4), Group activity (1), Practicing asking questions from experience (1)	Deep listening (3), Lesson-plan design (2), Mandala activity (1), Nature photography (1), Researching (1)

Table 3: (Continued) Initial reflections after class

Category	Week 1	Week 2	Week 3	Week 4
Challenges/ solutions	Little time / worked in free time (4), Technical problems / sought other channels (3), Lack of confidence in one's own knowledge (1)	Power outage / asked friends (4), Little time (1), Difficult content / asked questions (1)	No problem (3), Did not understand the instruction / looked at friends' work (1), Time limit / simplified complexity (1)	Finding materials for a mandala / used what was available (4), Internet / borrowed from others (1), Physical readiness (1), No problem (2)
Key takeaways	Seeking knowledge (4), Philosophy is life (3), Quoting philosophers (1)	Philosophy is the compass of education (3), Education is life (2), Are highly related (1)	Learning together (3), Link between education–philosophy (2), Harmonize (1)	Integrating all components (4), One should be open-minded when listening (2), Learning should not forget the dimension of life (2)

Table 3 presents graduate students' weekly reflections during the four-week instructional segment. Data were drawn from voluntary, ungraded journal entries. Numbers in parentheses indicate the number of respondents per item; individual graduate students may have contributed to multiple items.

From Table 3, graduate students' reflections varied across the four weeks in terms of emotional tone, perceived activities, and key takeaways. In Week 1, frequently reported descriptors included "enthusiastic" and "fun," whereas later weeks included terms such as "calm," "deep," and "self-review." Activities identified as impressive ranged from philosophical questioning and information searching in earlier weeks to deep listening and integrative design tasks in later weeks. Reported key takeaways also differed across weeks, as summarized in the table.

This shift may reflect cumulative engagement with the ESSENCE process, particularly the contemplative education activities introduced in the final week, which may have supported deeper reflective engagement among the graduate students.

Table 4: Analysis of learners' learning pathways over 4 weeks

Topic	Week 1	Week 2	Week 3	Week 4
What was learned	Meaning of philosophy (2), Four schools of philosophy (1), Questioning and critique (2), Philosophical concepts/schools (1)	Various schools of educational philosophy (3), Linking to the National Education Plan (1), Comparing ideas (1)	Various learning theories (3), Relationship between philosophy and theory (2), Integration into practice (1)	Contemplative education (4), Integrating contemplative education and the Sufficiency Economy (2)
Application in life	Questioning life (2), Self-reflection (2), Understanding cause–effect (1)	Analyzing ways of living (2), Understanding the environment and oneself (2)	Listening to others deeply (2), Analytical problem solving (1), Filtering knowledge (1)	Developing emotion, thinking, mind (2), Knowing oneself to live with others (2), Deep listening (1)
Application to the teaching profession	Designing instructional models (2), Building learner attributes (1), Stimulating thinking (1)	Setting a learning compass (2), Analyzing learner context (2), Designing assessment (1)	Selecting theories by content (2), Developing learners' thinking skills (2), Integrating theory with context (1)	Integrating learning activities (2), Engage learners in mindful presence (1), Deep listening to students (2)

Table 4 presents graduate students' reflections on their learning pathways across four weeks, categorized into three dimensions: content learned, application in life, and application to the teaching profession. Numbers in parentheses indicate the number of respondents per item; individual graduate students may have contributed to multiple items.

From Table 4, graduate students' reflections are reported across four weeks in three dimensions: content learned, application in life, and application to the teaching profession. Reported content included philosophical concepts, learning theories, contemplative education, and the sufficiency economy philosophy. Reflections related to life application addressed themes such as self-reflection, understanding of emotions, and interpersonal awareness. In the professional domain, responses included instructional design considerations, learner development, and practices such as deep listening and integration of learning activities.

These developments may reflect cumulative engagement with the ESSENCE process, particularly the contemplative activities introduced in Week 4, which may have supported deeper reflection and integrative thinking among the graduate students.

Table 5: Synthesis of learners' suggestions by category and week

Category	W1	W2	W3	W4	Example suggestions
Time management	6	6	2	–	"Adjust the time for some activities, e.g., information-searching activities" (W1); "Time for each activity should be increased so that information can be synthesized better" (W2)
Media and learning resources	3	2	4	1	"Add handouts to show the whole course and its content" (W1); "I would like more real case studies or sample teaching videos" (W3)
Teaching techniques	1	2	2	1	"Adjust the Canva 'build a school' activity because learners are diverse" (W2); "Summarize key points periodically for learners with less background" (W3)
Participation/reflection	1	1	2	3	"Propose activities for collaborative knowledge exchange" (W3); "Add reflection prompts from what was learned via video viewing" (W4)

Table 5: (Continued) Synthesis of learners' suggestions by category and week

Category	W1	W2	W3	W4	Example suggestions
Online constraints	1	1	–	–	"Equipment and facilities for learning do not support rapid submission" (W1); "Hold in-class learning in some weeks" (W2)
Satisfaction	1	1	4	5	"No need to adjust anything; today's activities are well-balanced" (W3); "No improvement needed" (W4)

Table 5 synthesizes graduate students' suggestions reported across four weeks and categorized by theme. Numbers indicate the frequency of comments per category per week, and example quotations illustrate representative feedback.

From Table 5, comments related to time management were reported most frequently in Weeks 1 and 2, with a total of 12 comments across these weeks. Satisfaction-related comments were also reported in later weeks, including four comments in Week 3 and five comments in Week 4 indicating that no improvement was needed. Suggestions related to media and learning resources, teaching techniques, and participation or reflection activities were reported across the four weeks, as summarized in the table.

These patterns may reflect graduate students' adaptive engagement with the ESSENCE process, as well as the increasing resonance of collaborative and contemplative elements introduced in the later weeks.

V. CONCLUSION AND DISCUSSION

Within a five-week instructional segment, the ESSENCE process served as a structured bridge between educational theory and instructional practice in a graduate-level Philosophy and Theory of Education course. While the full course addressed additional topics (e.g., educational quality assurance), the ESSENCE process was implemented over 27 hours—four weeks of instruction and one week of presentation—forming the core philosophical and theoretical component. Among learners with paired data (n = 9), post-instruction achievement increased from 16.20 to 23.11 out of 34 points, indicating a measurable improvement in learning achievement within this instructional context. Group Integrated Learning Units averaged 25.05 out of 30 (Good), with one group rated Excellent, demonstrating learners' ability to synthesize philosophical and educational theories with contemplative education and the sufficiency economy philosophy into coherent instructional designs. This synthesis reflects learners' capacity to integrate ethical discernment and inner awareness from contemplative education (Zajonc, 2013, pp. 83–84), alongside principles of moderation, reasonableness, and resilience

from the sufficiency economy philosophy (UNDP, 2007, pp. xv–xvi; UNDP, 2024, pp. 1–3; UNESCO, 2012, pp. 43–45). Reflective journals revealed a developmental trajectory from initial enthusiasm to more deliberate engagement: Week 1 responses included "fun," "exciting," and "meaningful," while Week 4 responses shifted to "calm," "deep," and "self-review." Key takeaways evolved from "seeking knowledge" and "philosophy is life" to "integrating all components" and "learning should not forget the dimension of life." This pattern suggests a gradual shift from externally focused engagement toward a more inward-oriented professional stance. Process feedback also changed over time, with early concerns about time and resources giving way to increasing satisfaction; notably, five learners in Week 4 stated "no improvement needed." Taken together, these patterns suggest that the ESSENCE process—through its combination of public reasoning, collaborative design, and guided reflection—supported learners in moving from "talking theory" to "doing theory in action," within the scope and limitations of this instructional context. Taken together, improvements in learning achievement, the quality of integrated learning unit design, and the depth of reflective engagement indicate that the ESSENCE process functions as an integrative pedagogical mechanism—supporting not only cognitive gains, but also design competence and reflective transformation in graduate-level instruction.

These findings align with mechanisms identified in the literature. Frequent, criterion-referenced feedback—delivered through formative quizzes and rubrics—likely supported learning improvement by tightening feedback loops and enabling instructional adjustment and self-regulated learning, consistent with contemporary formative assessment research (Carney et al., 2022, pp. 1–3). Collaborative work on Integrated Learning Units leveraged assisted performance within the zone of proximal development and scaffolding principles (Vygotsky, 1978, pp. 89–90; Wood et al., 1976, p. 90), enabling learners to complete tasks beyond their unaided capacity. Sequencing activities along the cycle of experience → reflection → conceptualization → experimentation followed the logic of Experiential Learning Theory (Kolb, 2015, pp. xxiii–xxiv), helping abstract ideas become testable instructional plans. Semi-structured reflective tasks—such as guided journals and small-group debriefs—aligned with research showing that structured reflection enhances reflective capacity (Phenwan, 2024, pp. 5–7). For an adult cohort of university lecturers, the ESSENCE process's emphasis on self-direction, experience-based inquiry, and problem-centered tasks resonated with the principles of Andragogy (Knowles et al., 2020, pp. 4–6). Ethical and reflective dimensions embedded in the ESSENCE process also align with contemplative education and the sufficiency economy philosophy, which emphasize personal transformation and sustainable decision-making in educational contexts (Zajonc, 2013, pp. 83–84; UNDP, 2007, pp. xv–xvi; UNDP, 2024, pp. 1–3; UNESCO, 2012, pp. 43–45). Finally, framing the course as collaborative inquiry about practice situated the work within the framework of Critical Participatory Action Research, which defines pedagogy as a practice-changing practice enacted through public, reason-giving deliberation (Kemmis et al., 2014, p. 30). This convergence between instructional design and research methodology strengthens the interpretive coherence of the findings.

SUGGESTION

The findings suggest that future studies applying the ESSENCE process should examine its effectiveness across larger and more diverse learner groups, compare its impact with other instructional models, and explore variations in online, hybrid, and in-person delivery formats. Longitudinal research is recommended to investigate sustained changes in learners' philosophical reasoning, reflective capacity, and professional attitudes following course completion. Further development of standardized tools—such as reflection-quality measures, integrative-design rubrics, and process-evaluation instruments—may strengthen validity and support broader adoption of the ESSENCE framework in graduate instruction.

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A DEVELOPMENT OF TRAIT INDICATORS FOR SERVANT LEADERSHIP OF TEACHERS IN BASIC EDUCATION SCHOOLS AND VOCATIONAL SCHOOLS UNDER THE MINISTRY OF EDUCATION

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ABSTRACT

The study conducted a second-order Confirmatory Factor Analysis (CFA) of servant leadership of teacher in basic education schools and vocational schools under the Ministry of Education, with findings based on empirical data. The sample for this research consisted of 1,200 participants, teacher in basic education schools, and teacher in vocational schools under the Ministry of Education, selected through multi-stage random sampling process. The research instrument was a five-point rating scale questionnaire that underwent content validity verification. The results were analyzed to determine the Item-Objective Congruence (IOC), with values ranging from .80 to 1.0. The item discrimination indices of the questionnaire ranged from .46 to .80, and the reliability analysis, using Cronbach's alpha coefficient, yielded a value of .95. The statistical method used for data analysis was CFA. The study results yielded six trait indicators for servant leadership of teacher in basic education schools and vocational schools under the Ministry of Education of six factors, include: valuing others 3 indicators, developing others 4 indicators, developing communities 4 indicators, demonstrating virtue 5 indicators, supporting leadership 4 indicators, and exercising shared leadership 5 indicators. The results of the examining the Goodness-of-Fit Index of CFA found the model fit indexes based on the empirical data were the Relative Chi-Square. (χ^2/df) = 1.242; RMSEA=0.022; SRMR=0.038; GFI=0.958; CFI=0.995; TLI=0.993; NFI=0.975; IFI=0.995. The factor loadings of six factors were from 0.739 – 0.914 and the reliability was at 0.546 – 0.835, indicating that all factors exhibit strong and acceptable loadings. The overall result of CFA measurement model demonstrates a good level of fit and construct validity.

Keywords: Servant leadership, Trait indicators, Confirmatory factor analysis, Basic education, Vocational education

I. INTRODUCTION

The concept of servant leadership originated from Greenleaf's theory, which posits that "true leadership begins with the intention to serve others" (Greenleaf, 1977, pp. 13–14). Since its introduction, this concept has been expanded and widely accepted as a leadership approach capable of strengthening and sustaining both organizations and society (Spears, 1998, pp. 3–11; Sendjaya & Sarros, 2002, pp. 57–64). Servant leadership has been extensively applied in business, nonprofit sectors, and particularly within educational administration, where leaders characterized by integrity and a commitment to developing others are (Liden et al., 2008, pp. 161–177; Bush, 2011, pp. 17–25).

Servant leaders function as moral exemplars within organizations. Through their compassion, honesty, generosity, and attentiveness to the needs of their followers, such leaders cultivate trust and voluntary cooperation without relying on control or coercion. This perspective corresponds with the findings of Wong et al. (2007, p. 9), who reported that servant leaders are able to create positive organizational climates that foster collaboration, moral-based decision-making, empathy, and long-term professional development. These attributes have contributed to the growing recognition of servant leader development as an essential focus in educational administration research. Although the core principles of servant leadership are broadly acknowledged, scholars differ in their definitions of its characteristics and components. Some researchers synthesize concepts from extensive bodies of literature to establish their own frameworks, whereas others adhere to foundational perspectives offered by influential theorists. For instance, Thompson (2005, p. 47) examined servant leadership among school administrators and identified at least ten key factors, including listening, empathy, maintenance, awareness, conceptualization, vision, and community development. Similarly, Bowman (2005, pp. 257–260) extended the concept of servant leadership to the role of teachers, emphasizing that these attributes can be enacted through teachers' everyday practices in classrooms and learning communities. Together, these perspectives illustrate that servant leadership encompasses not only compassion but also strategic thinking and the capacity to effect meaningful change. Similarly, Laub (2004, pp. 4–5) proposed six components of servant leadership: valuing others, developing others, demonstrating morality, providing leadership, sharing leadership power, and building organizational community. These dimensions have become widely utilized in leadership research due to their systematic structure and direct relevance to human capital development within organizations. Despite numerous efforts to conceptualize and define servant leadership, a notable gap persists in the development of valid and reliable indicators (Liden et al., 2008, pp. 161–177). This issue is particularly evident in the Thai context, where comprehensive studies on measuring servant leadership among teachers and educational administrators at both basic and vocational levels remain limited (Sisan, 2017, p. 863). The absence of contextually appropriate indicators presents challenges for systematically assessing and developing leadership practices within Thai educational institutions.

Given the distinct administrative structures, organizational culture, and expectations of parents, administrators, teachers, and other stakeholders within the Thai education system, adopting existing measurement tools from other countries may not be suitable. Thus, it is essential to develop assessment instruments that align with the cultural context and organizational dynamics of Thai education. Instruments that are psychometrically validated and contextually relevant can more accurately evaluate the leadership characteristics of teachers and administrators, thereby supporting more effective approaches to professional development.

Accordingly, this research aims to develop and validate indicators of servant leadership for use in educational institutions at both basic and vocational levels under the Ministry of Education. This effort seeks to produce a systematic assessment tool for evaluating teacher leadership and to provide a foundational database for advancing teacher professional development and improving institutional quality over the long term. The resulting instrument is expected to address the existing knowledge gap regarding servant leadership in the Thai context and serve as a basis for future research on educational leadership.

II. LITERATURE REVIEW

This research examines the concept of servant leadership from Laub (2004, pp. 4-5), which states that a servant leader is a leader with a sense of service, vision and work goals, understanding and guidelines for work. In addition, a servant leader is a good role model that supports and develops followers and the organization more than themselves. Laub's concept states that servant leadership consists of six components: valuing others, developing others, developing communities, demonstrating virtue, supporting leadership, and exercising shared leadership. In addition, Sisan (2017, p. 863) examined a confirmatory factor analysis (CFA) model of servant leadership among school directors under the Office of the Vocational Education Commission in Thailand, incorporating all six components of servant leadership and providing a CFA-based validation of the construct in the Thai educational context. Therefore, the components of servant leadership remain effective across different contexts and are well aligned with the Thai educational context, as they reflect cultural values emphasizing care, moral integrity, and collective responsibility.

In this study, the researcher used the conceptual framework to develop indicators of servant leadership characteristics of teachers in basic education institutions and vocational education institutions under the Ministry of Education, which consists of six components: 1) valuing others, 2) developing others, 3) developing communities, 4) demonstrating virtue, 5) supporting leadership, and 6) exercising shared leadership.

III. RESEARCH METHODOLOGY

The purpose of the research was to conduct a development of trait indicators for servant leadership of teacher in basic education schools and vocational schools under the Ministry of Education.

A. Participants

The research sample consisted of 1,200 participants, consisting of teachers in basic education schools and teachers in vocational schools. The sample size was determined according to the criteria set by Tabachnick and Fidell (2012, p. 618), who suggested that a sample size of 500 or more for CFA is considered excellent, particularly for complex models, to ensure stable parameter estimates, adequate statistical power, and reliable model fit evaluation. The multi-stage sampling process was carried out as follows: 1) Stratified random sampling was used, dividing the sample by school type, namely basic schools and vocational schools under the Ministry of Education. Then, the sample proportion was determined to be consistent with the proportion of each school type, selecting 600 samples per school type, resulting in a total sample of 1,200 (Creswell, 2014, pp. 158–161).

B. Variables

The variables are the dimensions of servant leadership, as shown in figure 1, and include: 1) valuing others, 2) developing others, 3) developing communities, 4) demonstrating virtue, 5) supporting leadership, and 6) exercising shared leadership.

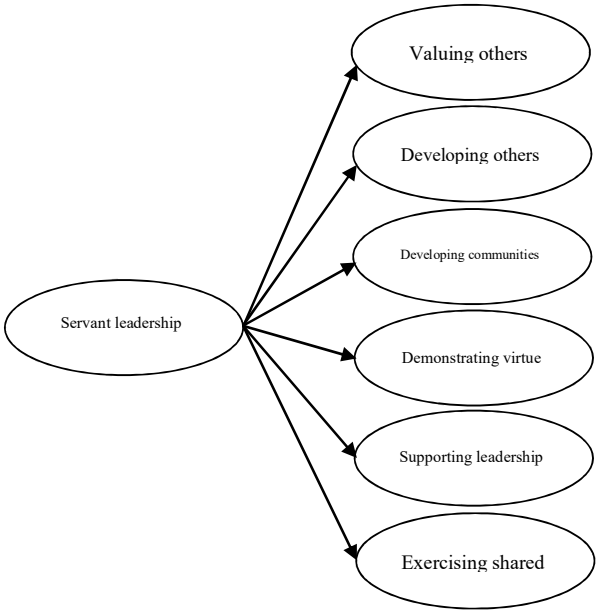


Figure 1: The dimensions of servant leadership

C. Research instrument

This study employed quantitative research methodology to examine the level of servant leadership of trait indicators of teacher in basic education schools and vocational schools under the Ministry of Education. The researcher developed a questionnaire based on the conceptual framework derived from a review of the literature, which was subsequently validated by five experts to assess content validity. The results were analyzed to determine the IOC, with values ranging from .8 to 1.0 for the questionnaire items used in this research (Rovinelli & Hambleton, 1977, pp. 49–60). The questionnaire was then piloted with 30 participants (A try-out group) including namely teacher in basic education schools and vocational schools under the Ministry of Education who were not part of the main research sample. The data were analyzed for discriminatory power using Pearson's simple correlation method by calculating the item-total correlation. The analysis revealed discrimination values ranged from .46 to .80, meeting the established criteria (Ebel, 1976, p. 128). Reliability analysis using Cronbach's alpha coefficient yielded an overall reliability of .95 (Cronbach, 1951, pp. 297–334).

The research questionnaire was administered through an online platform using google forms. The research instrument was a structured questionnaire employing a five-point Likert scale, with response options ranging from 5 (Strongly agree) to 1 (Strongly disagree) (Likert, 1932, pp. 1–55).The procedure for constructing a research questionnaire is presented in Figure 2.

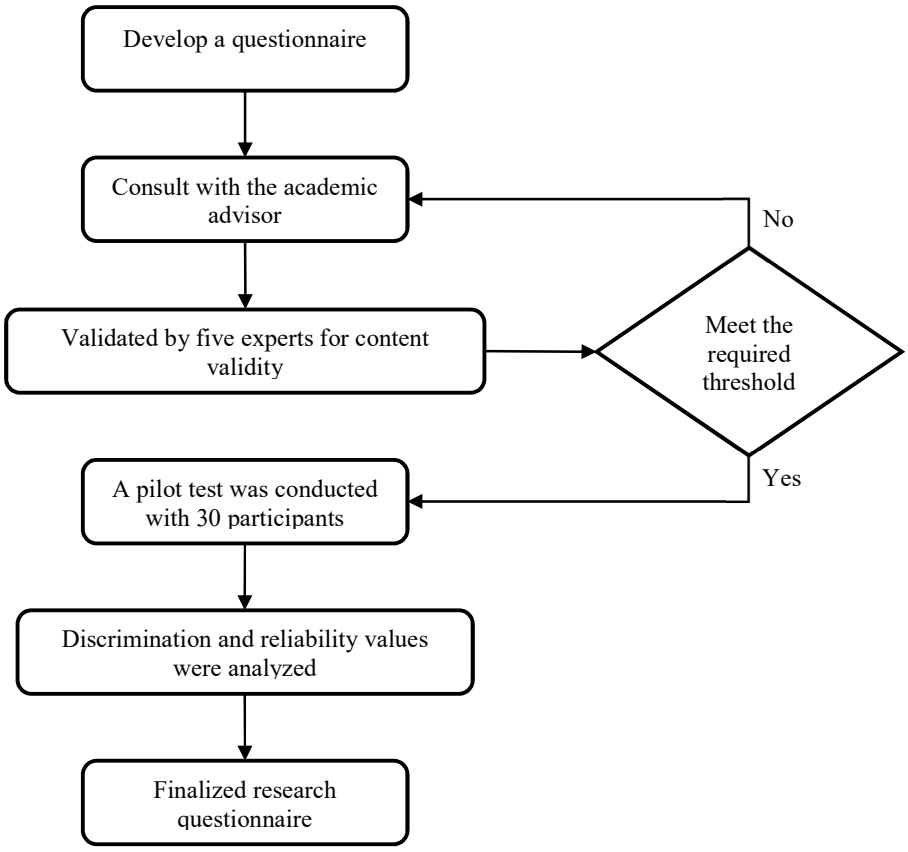


Figure 2: The procedure for constructing a research questionnaire

D. Data analysis

The researcher analyzed data using Jeffreys's Amazing Statistics Program (JASP) to process the data, calculate means, standard deviations, and perform second-order CFA toexamine constuct validity. Model fit was evaluated using multiple goodness-of-fit indices with reference to the criteria suggested by Hair et al. (2010, pp. 639-644), including χ^2/df (< 3.00), RMSEA (≤ 0.08), SRMR (≤ 0.08), and incremental fit indices (GFI, CFI, TLI, NFI, and IFI ≥ 0.90).

IV. RESULTS

Prior to analysis, the researcher verified preliminary assumptions for analyzing variable relationships, including examination of the Kaiser-Meyer-Olkin measure (KMO) to assess the suitability of the entire dataset for analysis. According to Hair et al. (2010, p. 104), the KMO value should exceed .5. The KMO value obtained from this analysis was .957. Additionally, Bartlett's Test of Sphericity was conducted to examine the overall relationships among variables, which, according to goodness-of-fit criteria, must be statistically significant (p-value < .05), indicating that the variables are sufficiently correlated to proceed with factor analysis.

The examination of the Goodness-of-Fit Index using CFA indicated that the model demonstrated an acceptable fit to the empirical data (Relative Chi-Square = 1.242, RMSEA = .022, CFI = .99, NFI = .98, SRMR = .038, RFI = .97, IFI = .99, and GFI = .96 (Sisan, 2017, p. 863). As shown in Table 1, these results indicate congruence of the second-order CFA measurement model for organizational resilience variables with the empirical data.

Table 1: Summary of fit indices

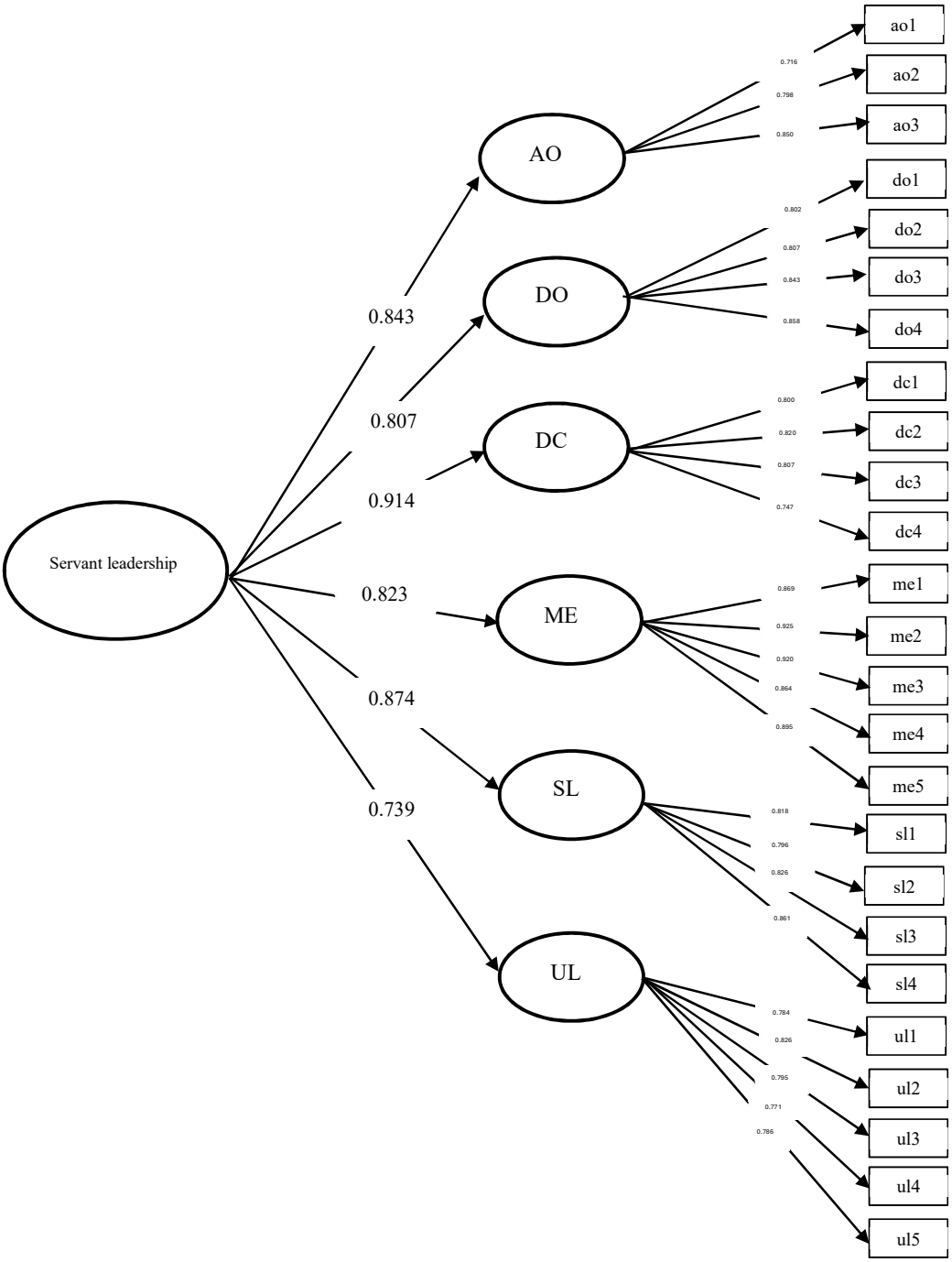
Index name	Index value	Accepted value	Status
χ^2/df	1.242	<2	Fit
RMSEA	.022	<.05	Fit
GFI	.95	>.90	Fit
CFI	.99	>.95	Fit
NFI	.98	>.95	Fit
SRMR	.038	<.08	Fit
RFI	.97	0 – 1	Fit
IFI	.99	>.90	Fit

The results of the data analysis revealed that trait indicators for servant leadership of teacher in basic education schools and vocational schools under the Ministry of Education comprises six main factors: include: valuing others(3 indicators), developing others(4 indicators), developing communities(4 indicators), demonstrating virtue(5 indicators), supporting leadership (4 indicators), and exercising shared leadership(5 indicators). The findings from the second-order CFA of servant leadership of teacher in basic education schools and vocational schools under the Ministry of Education indicate that all factor loadings exceeded the threshold value of .30 (Hair et al., 2010, p. 116). The factor loadings for the six latent constructs ranged from .73 to .91, with corresponding reliability coefficients ranging from .55 to .84.

The results of the Measurement Model analysis of trait servant leadership of teacher in basic education schools and vocational schools under the Ministry of Education found that the factor loadings of six factors were from 0.739 – 0.914, the reliability was at 0.546 – 0.835. Valuing Others has factor loadings of indicators from 0.716 – 0.850, the reliability was at 0.512 – 0.723. Developing Others has factor loadings of indicators from 0.802 – 0.858, the reliability was at 0.643 – 0.736. Developing Community has factor loadings of indicators from 0.747 – 0.820, the reliability was at 0.558 – 0.673. Moral Expressions has factor loadings of indicators from 0.864 – 0.925, the reliability was at 0.747 – 0.856. Supporting Leadership has factor loadings of indicators from 0.796 – 0.861, the reliability was at 0.669 – 0.742. Using Leadership Together has factor loadings of indicators from 0.771 – 0.826, the reliability was at 0.593 – 0.682. The detailed results of the data analysis are presented in Table 2 and Figure 3.

Table 2: Result of the measurement model analysis of trait servant leader of teacher in basic education schools and vocational schools under the Ministry of Education

Servant leader	Factor Loading SD estimation	SD.error	z-value	R^2
Valuing Others (VO)	**0.843**	**0.022**	**38.91**	**0.711**
X1 Respect for others' opinion	0.716	0.027	26.71	0.512
X2 Respect for others' decision	0.798	0.022	36.32	0.637
X3 Understanding of the others	0.850	0.020	42.68	0.723
Developing Others (DO)	**0.807**	**0.021**	**37.99**	**0.652**
X4 Developing ability of the others	0.802	0.020	41.01	0.643
X5 Developing personalities of the others	0.807	0.019	41.91	0.651
X6 Developing working skills of the others	0.843	0.016	51.74	0.711
X7 Developing minds of the others	0.858	0.015	55.80	0.736
Developing Community (DC)	**0.914**	**0.015**	**60.78**	**0.835**
X8 Making reliability and faith for community	0.800	0.021	38.48	0.640
X9 Solving problems and conflicts	0.820	0.019	42.18	0.673
X10 Making attitude of mind participation	0.807	0.020	41.01	0.650
X11 Supporting community and team	0.747	0.024	31.62	0.558
Moral Expressions (ME)	**0.823**	**0.018**	**44.99**	**0.677**
X12 Supporting morality of the others	0.869	0.013	66.55	0.755
X13 Accepting opinion of the others with morality	0.925	0.010	97.11	0.856
X14 Being good model continuously	0.920	0.012	78.17	0.846
X15 Honoring the others	0.864	0.013	65.43	0.747
X16 Sacrificing for the others	0.895	0.011	84.82	0.801
Supporting Leadership (SL)	**0.874**	**0.017**	**51.31**	**0.764**
X17 Making the others hopeful	0.818	0.019	42.20	0.669
X18 Positive thinking	0.796	0.020	40.18	0.633
X19 Motivation	0.826	0.017	47.26	0.683
X20 Making good personnel	0.861	0.015	57.55	0.742
Using Leadership Together (UL)	**0.739**	**0.025**	**29.29**	**0.546**
X21 Trusting and honoring colleagues	0.784	0.021	36.65	0.615
X22 Making proud of honoring others	0.826	0.017	47.62	0.682
X23 Being willful to develop the others to be leader in the future	0.795	0.021	38.55	0.631
X24 Being good leader and follower	0.771	0.021	36.42	0.593
X25 Supporting the personnel's working	0.786	0.020	39.14	0.618
χ^2/df =1.242; RMSEA=0.022; SRMR=0.038; GFI=0.958; CFI=0.995; TLI=0.993; NFI=0.975; IFI=0.995.				



χ^2 =268.260; df = 216; p-value=0.009; RMSEA=0.022

Figure 3: Results of the second confirmatory factor model analysis of servant leader of teacher in basic education schools and vocational schools under the Ministry of Education

The measurement model assessment was conducted through CFA, as presented in Table 3. The reliability analysis employed Cronbach's alpha coefficient (α), which should exceed .7, Composite Reliability (CR), which should exceed .6, and Average Variance Extracted (AVE), which should exceed .5 (Hair et al., 2010, p. 91). The Cronbach's alpha values obtained were in the range of .854 – .961, CR values were in the range of .804 – .971, and AVE values were in the range of .625 – .805. This indicated that reliability levels vary across constructs, with some demonstrating only moderate reliability and others showing good reliability and acceptable convergent validity.

Table 3: Results of the measurement model

Construct	α	CR	AVE
Valuing Others (VO)	.854	.804	.630
Developing Others (DO)	.903	.880	.683
Developing Community (DC)	.880	.853	.630
Moral Expressions (ME)	.952	.956	.805
Supporting Leadership (SL)	.899	.882	.677
Using Leadership Together (UL)	.896	.885	.625

V. CONCLUSION AND DISCUSSION

The research of the Measurement Model of trait servant leadership of teacher in basic education schools and vocational schools under the Ministry of Education found that the factor loadings of six factors were from 0.739 – 0.914, the reliability was at 0.546 – 0.835. Valuing Others has factor loadings of indicators from 0.716 – 0.850, the reliability was at 0.512 – 0.723. Developing Others has factor loadings of indicators from 0.802 – 0.858, the reliability was at 0.643 – 0.736. Developing Community has factor loadings of indicators from 0.747 – 0.820, the reliability was at 0.558 – 0.673. Moral Expressions has factor loadings of indicators from 0.864 – 0.925, the reliability was at 0.747 – 0.856. Supporting Leadership has factor loadings of indicators from 0.796 – 0.861, the reliability was at 0.669 – 0.742. Using Leadership Together has factor loadings of indicators from 0.771 – 0.826, the reliability was at 0.593 – 0.682. Therefore, the developed trait indicators of servant leadership among teachers in basic education and vocational schools under the Ministry of Education demonstrated good reliability and acceptable convergent validity. The researcher specified the indicator of the six factors from many researches. Then, there was analysis of content accuracy by experts to examine the reliability of the instrument and finally found the acceptable. Prior to data collection, the variables within each factor were ensured to be measurable. Relevant documents were systematically reviewed and examined to identify appropriate and effective indicators. After collecting information, that information must be analyzed to measure accuracy or the variable, or indicators used to measure the variable, or indicators used to measure the variable, there must be consideration of factor loading in the matrix LX or LY. Factor loading must be high and have statistical significance, z-value is more than 1.960 (Diamantopoulos et al., 2000, p. 85). Moreover, there must be CR and AVE (Hair et al., 2010, p. 91). The reliability of latent variable should be more than 0.600 (CR≥0.600) and mean of variance of latent variable should be more than 0.500 (AVE≥0.50) The analysis result of factor Valuing Others, CR is at 0.804 and AVE is at 0.630.

The analysis result of the factor Developing Others, CR is at 0.880 and AVE is at 0.683. The analysis result of the factor Developing Community, CR is at 0.853 and AVE is at 0.630. The analysis result of the factor Moral Expressions, CR is at 0.956 and AVE is at 0.805. The analysis result of the factor Supporting Leadership, CR is at 0.882 and AVE is at 0.677. The analysis result of the factor Using Leadership Together, CR is at 0.885 and AVE is at 0.625 It showed that all factors passed the criteria. To design this research, there was specification of sample used in the research by probability. Then, the sample groups are from multi-stage random sampling. Hence, it is able to reflect the Goodness-of-Fit (GoF) index in CFA.

Reason that supports my result were the developmental issues in servant leadership, such as the challenges facing empirical investigation and measurement, and the changes that are occurring in current thinking about the servant leadership approach. (Gregory et al., 2004, pp. 359-361) The results produced five servant leadership factors—altruistic calling, emotional healing, persuasive mapping, wisdom, and organizational stewardship—with significant relations to transformational leadership, leader- member exchange, extra effort, satisfaction, and organizational effectiveness. Strong factor structures and good performance in all validity criteria indicate that the instrument offers useful for future research (Barbuto et al., 2006, p. 300). The current developmental stage of the servant leadership movement is explored in order to provide some useful signposts for future research directions (Sendjaya et al., 2002, p. 57). Also Brien N. Smith, Ray V. Montagno, Tatiana N. Kuzmenko suggested that servant leadership leads to a spiritual generative culture, while transformational leadership leads to an empowered dynamic culture. The paper also addresses contextual factors which might make one or the other models more appropriate for organizational objectives (Smith et al., 2004, p. 86) and Robert F. Russell found that the servant leadership theory and extrapolate applications of the values in leadership literature led to three aspects of servant leadership: trust; valuing others; and empowerment. Leader values may be the underlying factors that separate servant leaders from all other leadership types (Russell, 2001, p. 76). Consistent with previous servant leadership research, (Farling et al., 1999, p. 51) found that a servant leadership model is based on five key variables: vision, influence, credibility, trust, and service, as identified in both academic and popular literature.

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