IJIET
INTERNATIONAL JOURNAL
of Industrial Education and Technology

2025
JANUARY - JUNE
7th YEAR 1st EDITION

International Journal of Industrial Education and Technology
ISSN 2673-0448
Vol. 7 No. 1 (January–June) 2025

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Submission: Continuously

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Publication on academic and research articles in the terms of **Industrial Education** and **Education and Technology** in specific fields as

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Editorial Statement

As an editor in chief of International Journal of Industrial Education and Technology (IJIET), I would like to welcome and present you Volume 7 number 1, IJIET 7(1), in 2025, which is mainly focuses on industrial education, education and technology in five sections follow 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. For this IJIET issue, review article is on "QUANTIFYING PRECIPITABLE WATER VAPOR USING THREE-DIMENSIONAL RADIOSCOPY FROM OBSERVATIONS WITH GPS, BDS, AND GLONASS SATELLITES" and book review is about "AIR POLLUTION: AN INTRODUCTION TO ITS CAUSES, EFFECTS, AND SOLUTIONS". I would like to invite you to read all the interesting contents authored by the professional and intelligent group of writers to share their outcomes of research and professional discussions.

On behalf of the editorial boards, I would like to sincerely delight to thank you very much for your kindly 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)

	Contents	Page
	Review Article	
01	QUANTIFYING PRECIPITABLE WATER VAPOR USING THREE-DIMENSIONAL RADIOSCOPY FROM OBSERVATIONS WITH GPS, BDS, AND GLONASS SATELLITES **Supawit Nambut**	A1-A6
	Book Review	
02	BOOK REVIEW: AIR POLLUTION: AN INTRODUCTION TO ITS CAUSES, EFFECTS, AND SOLUTIONS Authors: Laura Hyesung Yang, Jiwon Kim, Dha Hyun Ahn **Pattawut Wongsak**	B1-B5
	Research Articles	
03	FORESIGH 2024-2034: THE FUTURE LANDSCAPE OF EDUCATIONAL TECHNOLOGY AND COMMUNICATIONS MANAGEMENT IN THAILAND'S VOCATIONAL INSTITUTIONS **Sutisa Songsri, Chatchawan Chumraksa, and Pattana Sirikunpipat**	1-16
04	THE EFFECT OF DIGITAL GAME-BASED LEARNING USING QUIZLET ON EFL STUDENTS' PERFORMANCE AND MOTIVATION **Jing Li and Thanawan Phongsatha**	17-27
05	USING EYE-TRACKING TECHNOLOGY TO ASSESS CONSUMER INTEREST IN THE GRAPHIC DESIGNS ON VITAMIN WATER PACKAGING **Suchada Kuntaros, Wasan Sornkhieo, Risara Bubhawong, and Nuttawut Patchanee, Sirivimon Saywech**	28-45

	Contents	Page

INTERNATIONAL JOURNAL of Industrial Education and Technology

QUANTIFYING PRECIPITABLE WATER VAPOR USING THREE-DIMENSIONAL RADIOSCOPY FROM OBSERVATIONS WITH GPS, BDS, AND GLONASS SATELLITES

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Received: June 20, 2025 **Revised:** June 23, 2025 **Accepted:** June 24, 2025

Citation reference :
Nambut, S. (2025). Quantifying precipitable water vapor using three-dimensional radioscopy from observations with GPS, BDS, and glonass satellites. **International Journal of Industrial Education and Technology, 7** (1), A1-A6.

ABSTRACT

This review article presents information and academic documents related to measuring precipitable water vapor in the atmosphere using 3D radioscopy by three satellite systems: GPS, BDS, and GLONASS. The review article presented the three methods to compare the differences in using a single satellite system, two satellite systems, and three satellite systems, respectively, which can measure the amount of precipitable water vapor in the atmosphere using 3D radioscopy. In addition to being beneficial for measuring precipitable water vapor in the atmosphere through photographic methods, it can also serve as a tool for research in forecasting precipitable water vapor for agricultural crop cultivation by farmers according to different seasons, predicting air humidity, rainfall, meteorological department reports, and monitoring global climate change.

Keywords: GNSS, Global positioning system, 3-D water vapor precipitable, Precipitable water vapor, ZTD, ZHD, ZWD

I. INTRODUCTION

The atmosphere contains water vapor, which is a crucial variable for all living things on this planet. Water vapor is extremely important as it drives the life processes of living organisms (National Aeronautics and Space Administration [NASA], 2025, Online). It regulates the body temperature of humans, animals, plants, and others. It is essential for farmers in the agricultural sector, such as in crop cultivation and livestock raising. The hydrological cycle of water vapor depends on the variable amount of water vapor and the average concentration in the atmosphere, which is influenced by factors such as geographical characteristics or different seasons. The measurement of water vapor in the atmosphere has been ongoing for a long time, with meteorologists seeking various methods and techniques to calculate the amount of water vapor.

From the study of the Global Positioning System (GPS) by Bevis et al. (1992, pp. 15787-15801), which serves as a guideline for estimating atmospheric water vapor using GPS satellites, this method has been explored due to its cost-effectiveness. The amount of water vapor in the atmosphere can be inferred from the signal propagation errors of GPS satellites passing through the tropospheric layer. These errors are considered parameters and are eliminated in the process of estimating the coordinates of the surveying station. The estimation of the tropospheric layer's wet part from Very Long Baseline Interferometry (VLBI) and GPS surveying is close to the estimates from radiosondes and microwave radiometers (Lu et al., 2016, pp. 703-713). However, the measurement using microwave radiometer and radiosonde requires a significant budget and only provides data in certain areas. Therefore, these methods have become another option that meteorologists use.

In this review study, GNSS technology is integrated and applied to the study of precipitable water vapor in the atmosphere using 3D radioscopy with GNSS satellite systems (Dong et al., 2018, pp. 1-15). The applications include single-system, dual-system, and triple-system approaches, which demonstrate that more satellites in GNSS systems such as GPS, BeiDou, and GLONASS increase accuracy.

II. WATER VAPOR

Steam refers to water that has evaporated, characterized by its purity and colorlessness, resembling mist. At normal pressure, water turns into steam at a temperature of 100 degrees Celsius, expanding to about 1,600 times its liquid volume. Steam can reach very high temperatures (above 100 degrees Celsius), known as superheated steam, when liquid water comes into contact with high-temperature objects such as hot metals or lava. Water can instantly turn into vapor (Ahrens, 2012, pp. 91-93).

Humans cannot see water vapor with the naked eye, but on clear days, there is water vapor everywhere. This is because water vapor is a colorless, odorless gas, so it cannot be directly perceived through touch, which may differ from clouds formed by liquid water droplets. It is nothing more than the change in the state of water vapor when the phase changes from liquid to gas. This water vapor is colorless and odorless, although it usually appears white and cloudy when mixed with small liquid water droplets. The visibility decreases depending on the factor of density. For example, we can see that steam can be quite visible when we leave the bathroom and close the bathroom window. This is where the steam accumulates and turns into liquid when it condenses on the walls.

III. 3-D WATER VAPOR TOMOGRAPHY

3D radioscopy with satellite systems for capturing images to determine the amount of water vapor in the atmosphere, using pixel observation methods. The observation model assumes a spatial relationship between the water vapor in specific pixels and the surrounding pixels. General constraints are applied, including horizontal constraints, vertical constraints, and boundary constraints.

METHODOLOGY

The principle tomography technique is to use the integral observation reconstruct the detailed information to the studied object through a certain mathematical constraint. In GNSS meteorological, the integral observation of tropospheric tomography are SWV, with the movement of satellites system in space and the rotation of Earth, and dense GNSS observations can retrieve the 3-D water vapor over interested area with the tomography technique.

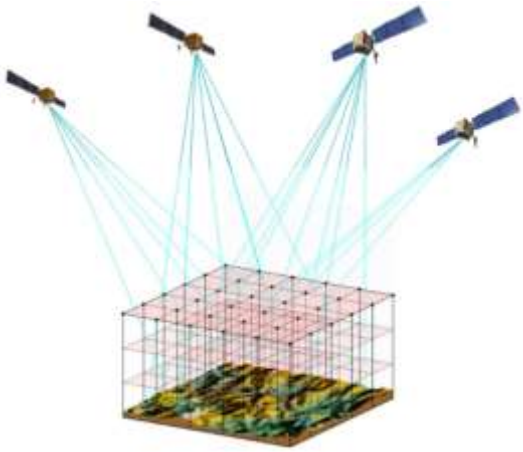

Figure 1: The principle of GNSS tropospheric water vapor tomography

B. EQUATION

Determination of dry vertical tolerances.The value can be calculated if we know the air surface pressure (Ps) at the station location from the equation (Bevis et al., 1992, pp. 15787-5801) and wet vertical tolerances.

$$ZHD = \frac{2.2768\ XPs}{1-0.00266\cos(2\ \emptyset)-0.00000028H} \quad (1)$$

This is caused by the amount of water vapor present in the atmosphere, which can be calculated from the equation (Bevis et al., 1992, pp. 15787-15801).

$$ZWD = ZTD - ZHD \quad (2)$$

ZWD (Zenith Wet Delay) is in millimeters.

The resulting ZWD value can be used to calculate the amount of water vapor in the atmosphere from the relationship from the equation getting the amount of water vapor in the atmosphere in millimeters.

$$PWV = ZWD * \prod \quad (3)$$

Where the coefficient $\prod$ can be estimated from the equation (Bevis et al., 1992, pp. 15787 - 15801).

$$\prod = \frac{10^6}{Pw\ x\ Rv+(\frac{K3}{Tm}+k'2)} \quad (4)$$

where as

P_w = density of water in liquid state. (999.97 kg/m^3)
R_v = Steam constant (461.525 joules/kg*Kelvin)gg
k'_2 = refractive constant in the troposphere (22.1 Kelvin/mbar)
k_3 = refractive constant in the troposphere (3,739 $Kelvin^2$/mbar)
T_m = Average temperature of the troposphere (Kelvin)h

In the process of determining the T_m value at any given time, it is difficult to make accurate measurements. It also requires processing time. Another option is to estimate using mathematical models, which take the form of linear relationships with surface temperature data at station locations.

The observations of the tropospheric water vapor tomography are the integration of water vapor in the direction of the ray – path slant water vapor (SWV) which can be expressed as:

$$SWV = \int_l p\,(l)dl = PWV * M_w + R \quad (5)$$

where

p (l) = represent the water vapor density
dl = Specifies the length of a signal element
M_W = is the wet mapping coefficient
R = the non - homogeneous variation of the water vapor

IV. RESULTS REVIEW

The research findings indicate that, based on the comparison of root mean square (RMS) values and relative errors between the water vapor density obtained from ERA5 and the GNSS tomography results, which differ from UTC 6:00 to 18:00 over a seven-day period across various layers, the amount of water vapor tends to decrease with increasing altitude. It was also found that the RMS values using two and three satellite systems are better than those using only the GPS satellite system. This demonstrates that a multi-satellite system increases accuracy even further in Figure 2. It is using the GPS satellite system alone (G), the GPS system with BDS (G+C), the GPS and GLONASS satellite systems (G+R), and the GPS, BDS, and GLONASS satellite systems (G+R+C).

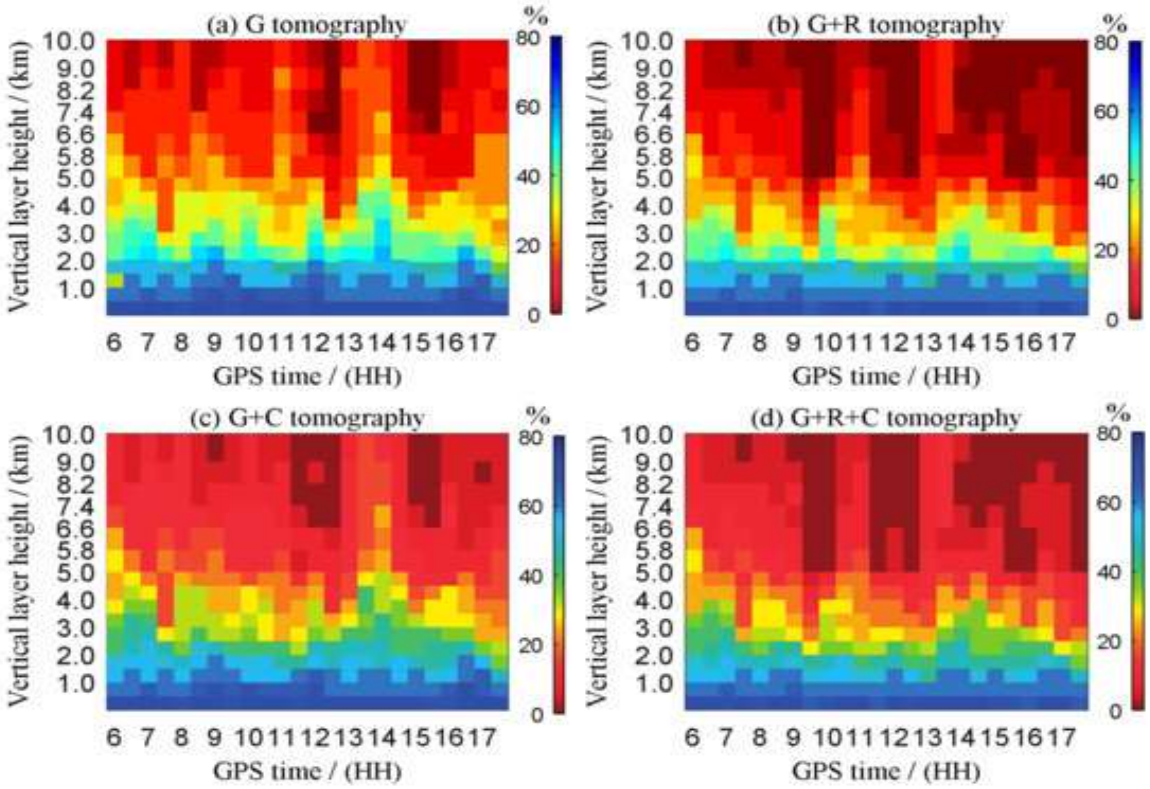

Figure 2: The percentage of empty voxels with different combined GNSS in different layers

V. CONCLUSION AND DISCUSSION

The conclusion from the study of the above article, which has the same objective of water vapor tomography using three satellite systems, namely GPS, BDS, and GLONASS. All four methods use different satellite systems, but they share the same objective: to determine the water vapor density through imaging (Tomography). It was found that as the height of the atmosphere increases, the amount of water vapor tends to decrease. Additionally, the RMS values of the two-system and three-system satellite configurations are better than using the GPS satellite system alone. This indicates that more satellite systems increase accuracy in determining atmospheric water vapor density. Changes in atmospheric water vapor are partly due to human activities, which in turn can lead to global changes. This study is interesting and may serve as a good method and guideline for future research. From this study, it is interesting and may be another good method that is suitable and can be used as a guideline for research by Dong et al. (2018, pp. 1-15).

AKNOWLEDGEMENT

The author would like to thank Associate Professor Dr.Prasert Kenpankho, Department of Engineering Education, School of industrial education and technology, King Mongkut's Institute of Technology Ladkrabang, Thailand, for giving and consulting on the Global Positioning system and precipitable water vapor.

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INTERNATIONAL JOURNAL of Industrial Education and Technology

BOOK REVIEW: AIR POLLUTION: AN INTRODUCTION TO ITS CAUSES, EFFECTS, AND SOLUTIONS
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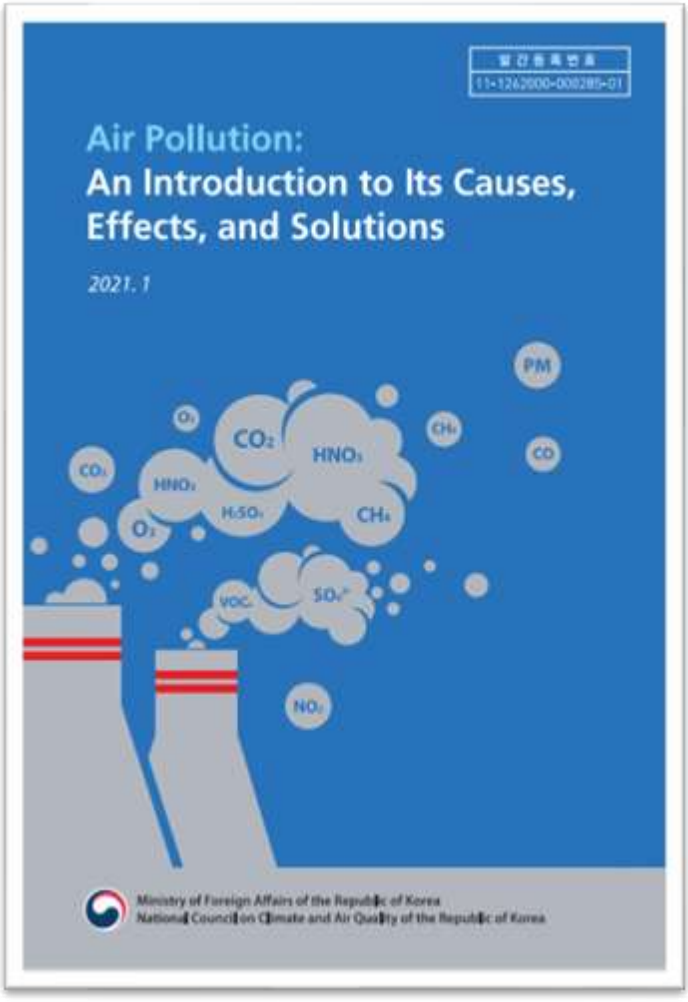
Received: June 20, 2025 **Revised:** June 23, 2025 **Accepted:** June 24, 2025

Citation reference :
Wongsak, P. (2025). Book review: Air pollution: An introduction to its causes, effects, and solutions - Authors: Laura Hyesung Yang, Jiwon Kim, Dha Hyun Ahn. **International Journal of Industrial Education and Technology, 7** (1), B1 - B5.



ABSTRACT

I have reviewed Air Pollution: An Introduction to Its Causes, Effects, and Solutions, a comprehensive 2021 publication by the Ministry of Foreign Affairs and NCCA of the Republic of Korea. This book provides an insightful overview of air pollution - from present status and pollutants to impacts and solutions - in support of the UN's International Day of Clean Air for blue skies. The book is richly informative, combining up-to-date statistics and case studies to illustrate how air pollution has become the world's leading environmental health risk. By covering both outdoor and indoor pollution and linking air quality to public health, climate, and sustainable development, it offers a valuable guide for diverse stakeholders. I found this volume to be a highly useful resource that not only deepened our understanding of air pollution's causes and consequences but also highlighted practical measures and cooperative efforts needed to combat this global challenge. Overall, the book serves as an excellent reference for students, researchers, and policymakers interested in environmental management and public health.

Keywords: Air pollution, Global health, Environment, Sustainable development, Public policy

INTRODUCTION

The book opens by underlining that air pollution is the single largest environmental threat to human health worldwide, accounting for an estimated 7 million premature deaths annually. This toll makes dirty air deadlier than malaria, tuberculosis, and HIV/AIDS combined. The introduction emphasizes how both ambient (outdoor) and household (indoor) air pollution contribute to this crisis, disproportionately affecting vulnerable groups such as women, children, and the elderly in developing countries.

About 4.2 million annual premature deaths are attributed to ambient air pollution (from heart and lung diseases and infections), while the remainder are linked to indoor pollution from cooking fuels. This framing underscores the dual nature of the problem and the urgent need for solutions on multiple fronts. Crucially, the authors situate the discussion in a global policy context. The United Nations General Assembly's 2019 Resolution 74/212 designated September 7 as the International Day of Clean Air for blue skies, a day of awareness and action advocated by the Republic of Korea.

The book was prepared as a key reference for the first observance of this Clean Air Day in 2020, themed "Clean Air for All," aiming to galvanize international solidarity for air pollution and climate action. The introduction highlights this backdrop, stressing the need for strengthened international cooperation, data-sharing, joint research, and best-practice exchange to tackle air pollution collectively. By linking to the UN initiative, the book immediately establishes the importance and timeliness of its content. Overall, the introduction effectively sets the stage, conveying the gravity of air pollution's health impacts and the high-level commitment to solutions – a theme that resonates throughout the subsequent chapters.

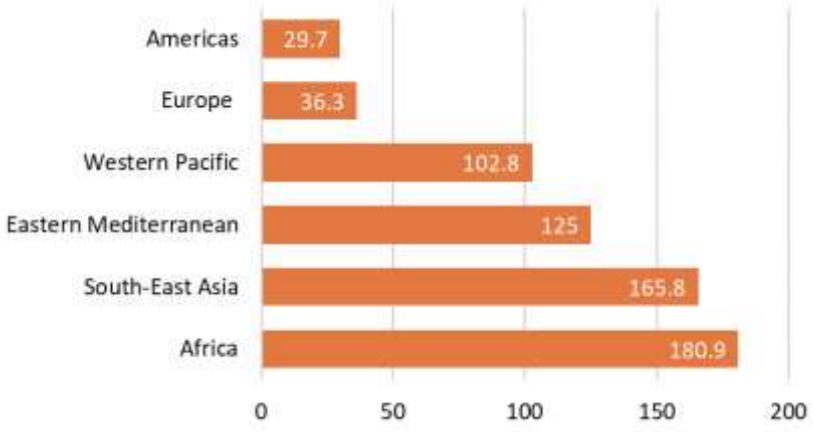


Figure 1: Age-standardized annual death rate (per 100,000 people) attributable to air pollution by WHO region (2016 data)

BOOK STRUCTURE

Air Pollution: An Introduction to Its Causes, Effects, and Solutions is organized into nine chapters, each addressing a key question about air pollution. The structure follows a logical progression from understanding the problem to exploring solutions.

Chapter 1 examines global trends and patterns in air pollution-related deaths, with data showing regional disparities and changes over time. Chapter 2 introduces primary and secondary air pollutants such as particulate matter (PM2.5 and PM10), ozone, carbon monoxide, sulfur dioxide, nitrogen oxides, and volatile organic compounds. It explains their sources, behaviors, and health effects.

Chapter 3 categorizes pollution sources into natural, mobile, stationary, and area-based sources, offering examples such as forest fires, vehicle emissions, industrial processes, and household activities. Chapter 4 explores the consequences of air pollution, including its severe health impacts (e.g., respiratory diseases, cardiovascular issues), environmental effects (acid rain, climate change), economic costs, and its links to the UN Sustainable Development Goals (SDGs).

Chapter 5 focuses on indoor air pollution, identifying common pollutants, their sources, and interventions to reduce exposure, especially in developing countries. Chapter 6 outlines how air pollution is monitored and managed, introducing the Air Quality Index (AQI), surveillance systems, and WHO guidelines.

Chapter 7 details mitigation strategies and policy actions categorized by sector and stakeholder responsibility. Chapter 8 emphasizes the importance of regional and international cooperation in addressing transboundary pollution issues. Finally, Chapter 9 compiles resources, including policy documents, health reports, and useful websites, guiding readers toward deeper engagement with the topic.

This structured layout supports both comprehensive reading and targeted consultation, making the book a versatile reference for various audiences.

REFLECTION

This book publication offers a comprehensive yet accessible overview of air pollution, making it a valuable resource for a broad audience including students, educators, policymakers, and environmental advocates. One of its strengths is the clear structure and use of up-to-date, evidence-based information from trusted sources like WHO and UNEP. The question-driven format makes complex topics more digestible, while the visual aids and real-life examples enhance reader engagement.

Despite being an introductory text, it covers a wide scope-from pollutant chemistry to policy frameworks. However, readers seeking technical depth or critical policy analysis may find some sections simplified. The book avoids overly technical jargon, which increases its usability for non-specialists but may limit its utility for advanced researchers. Nevertheless, its strengths in clarity, organization, and global applicability outweigh these limitations. As an educational and policy-aligned reference, it successfully communicates the urgency and complexity of air pollution and encourages coordinated action at all levels.

CONCLUSION

Air Pollution: An Introduction to Its Causes, Effects, and Solutions is a commendable and timely contribution in the field of environmental science and policy literature. It succeeds in its core mission to educate and inform: by providing a holistic overview of air pollution's causes, impacts, and remedies, the book fills an important niche for a single, go-to reference on this subject. The formal yet accessible style, coupled with a logical structure, makes it suitable for a wide readership – from environmental professionals and academics seeking a quick refresher or teaching tool, to policymakers and international agency personnel looking for a consolidated briefing, to students and concerned citizens aspiring to understand air quality issues. The publication's alignment with the UN's International Day of Clean Air demonstrates its real-world relevance and strategic framing as part of a global call to action. As the world grapples with the twin challenges of pollution and climate change, this book provides both knowledge and inspiration by affirming that solutions are known and within reach if stakeholders collaborate and act decisively. It stands as a valuable reference that not only charts the problem of air pollution with scientific rigor but also illuminates the path forward through evidence-based policy measures and cooperative efforts. In conclusion, the book is an authoritative introductory guide that will be useful for years to come as governments, educators, and communities worldwide work together to ensure cleaner air and healthier futures.

ACKNOWLEDGEMENT

I would like to thank Associate Professor Dr. Prasert Kenpankho from the Space, Satellite, and Study Laboratory (SSS Lab), Department of Engineering Education, King Mongkut's Institute of Technology Ladkrabang, Thailand, for his valuable guidance and consultation during the preparation of this review. His insights and expertise in environmental systems and atmospheric studies were instrumental in enhancing the academic rigor of our work.

REFERENCE

Yang, L. H., Kim, J., & Ahn, D. H. (2021). *Air pollution: An introduction to its causes, effects, and solutions*. Ministry of Foreign Affairs of the Republic of Korea & National Council on Climate and Air Quality of the Republic of Korea.

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INTERNATIONAL JOURNAL of Industrial Education and Technology

FORESIGH 2024-2034: THE FUTURE LANDSCAPE OF EDUCATIONAL TECHNOLOGY AND COMMUNICATIONS MANAGEMENT IN THAILAND'S VOCATIONAL INSTITUTIONS

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Received: April 22, 2025 **Revised:** May 13, 2025 **Accepted:** May 17, 2025

Citation reference :
Sogsri, S., Chumraksa, C., Sirikunpipat, P., & Kasinanat, C. (2025). FORESIGH 2024-2034: The future landscape of educational technology and communications management in Thailand's vocational institutions. **International Journal of Industrial Education and Technology, 7** (1),1-16.

ABSTRACT

This research aimed to: (1) investigate prospective scenarios of educational technology and communications management in Thai vocational schools for the period 2024-2034, and (2) offer policy recommendations for their advancement utilising the Ethnographic Delphi Futures Research (EDFR) approach. The study had three phases: 1) Conduct a literature research and analysis utilising the AECT (2012) framework, focusing on pertinent theories and documents. The AECT (2012) framework includes five fundamental standards: content knowledge, content pedagogy, learning settings, professional knowledge and skills, and research. 2) employed the EDFR technique with a panel of 22 experts, comprising five senior management officials from the Office of the Vocational Education Commission, three university lecturers specialising in educational technology and communications, two educational supervisors, college administrators, six instructors, and one representative from an educational technology enterprise. There are three rounds in the EDFR method. Semi-structured interviews were done in Round 1. In Round 2, a questionnaire was designed based on the expert interviews and disseminated to the same cohort. In Round 3, experts were provided with statistical feedback, comprising percentage values, median, and interquartile range (IQR), in conjunction with their prior responses. They were thereafter requested to validate or amend their responses. 3) The results identified five developing trends in content knowledge, four in content pedagogy, six in learning environments, eleven in professional knowledge and skills, and four in research. Twelve policy proposals were presented to direct the advancement of educational technology and communications management in Thai vocational schools during the upcoming decade (2024-2034).

Keywords: Educational technology, Vocational schools, Management, Educational technology and communications management, Ethnographic Delphi Futures Research

I. INTRODUCTION

In contemporary society, technology significantly influences daily life, especially in education, where it plays a pivotal role in enhancing teaching and learning quality. The government, recognizing this, has highlighted the importance of developing educational technology and innovation through the National Education Act of 1999, Section 64, which focuses on equipping personnel with the necessary knowledge and skills for effective use and production of technology in education. Section 64 of Thailand's National Education Act serves as the legal foundation for educational technology development. It mandates: (1) capacity-building programs for educators through practical training workshops; (2) development of quality digital learning resources; and (3) establishment of institutional technology systems. This comprehensive approach enhances digital literacy, bridges classroom technology gaps, and modernizes Thailand's education system for the digital age. The National Education Act (No. 2) B.E. 2545 (2002) serves as Thailand's framework for modernizing education by integrating 21st-century skills into curricula. It promotes educational technology (EdTech) through digital learning platforms, teacher training, and infrastructure development. Technology in education applies various tools to improve the efficiency and effectiveness of learning processes. It also helps bridge educational gaps by ensuring equal access to information. Furthermore, technology underpins human resource development in the country by facilitating distance learning, telecommunications, and modern educational tools, such as internet access, which support global knowledge retrieval

Vocational education management is essential for producing skilled labor, contributing to national, economic, and societal development, and meeting the growing demands of business and industry. The Vocational Education Act (Section 6) aligns vocational education with national development plans to produce skilled workers at various levels. The Office of the Vocational Education Commission aims to create a high-quality workforce using modern technology to meet national strategic goals. Thailand ranks low (56th) in Infrastructure (Education), highlighting the need for improved educational technology to boost competitiveness and sustainability (Research and Innovation Policy Council, 2021, p. 1).

The recent crisis has driven changes in educational technology, significantly impacting vocational education for hundreds of thousands of students in Thailand across social, economic, and learning dimensions with shifting economic conditions, the demand for vocational workers has changed in both quantity and quality (Paweenawat & Liao, 2021, pp. 26-27). Developing skilled labor must align with technological changes and new innovations entering industries. Additionally, a study on factors influencing the success of vocational education management found that educational technology and communications play a crucial role. Vocational education thrives when aligned with real-world industry needs, and educational technology (EdTech) and communications serve as transformative pillars in achieving this alignment. However, challenges such as outdated equipment and insufficient resources hinder effectiveness. Support for modern technology and adequate resources is essential to improve efficiency and reduce operational time.

The office of the Vocational Education Commission emphasizes enhancing vocational education management through Digital Transformation, focusing on developing high-competency workers who continuously adapt to future development goals, driven by technology across all learning processes (Butrasenlee, 2022, pp. A-L). Due to changes in educational technology and communications, as well as the evolving demand for vocational education personnel, this research aims to explore the scenario of educational technology and communications management in vocational schools in Thailand for the period 2024-2034. The study follows AECT, 2012 standards: (1) content knowledge, (2) content pedagogy, (3) learning environments, (4) professional knowledge and skills, and (5) research. Additionally, the research will provide

policy recommendations for the development of vocational education colleges. The findings will provide valuable insights for educational leaders and stakeholders to guide effective planning and decision-making in developing educational technology and communications strategies in vocational education, ensuring alignment with the country's context

II. LITERATURE REVIEW

Educational technology and communications, Andrew et al. (2008, p. 294) define educational technology, according to AECT, as a systematic approach to developing solutions for educational challenges, utilizing available resources such as personnel, management, and learning environments. Malitong (2015, p. 17) states that educational technology is a combination of resources and processes that support learning, enabling teachers to use technology and innovations to enhance teaching. Learning is not limited to the classroom and can occur anywhere, depending on the situation. In summary, educational technology involves applying techniques, tools, and knowledge to improve teaching and foster effective learning outcomes.

The role of educational technology and communications, Phromwong (2013, p. 14) explains four roles of educational technology and communications: as knowledge: refers to curricula designed to equip students with skills in educational technology, such as instructional design, media, and telecommunications, as an administrative tool: Involves roles in system management, clerical tasks, personnel and academic management, communication, and staff development, as an academic tool: includes teacher-centered and object-centered learning approaches, such as distance learning using various media, for academic service: helps in disseminating knowledge through media, offering continuous education, and providing research services. Diteeyont and Yoosamran (2021, p. 333) highlight the roles of educational technology in preparing the education system, promoting equality, and fostering global learning opportunities. In summary, educational technology has been and will continue to be crucial for educational management, offering innovation, expanding opportunities, and ensuring accessible learning for all members of society. Scope of educational technology and communications, Association for Educational Communications and Technology [AECT] (2012, Online) consists of five components as follows: 1) content knowledge, to demonstrate the necessary knowledge for creating, using, evaluating, and managing the application of educational technology and processes, both theoretically and practically, 2) content pedagogy, to develop as practitioners who can effectively apply educational technology and processes, considering contemporary content and teaching methods, 3) learning environments, to facilitate learning by creating, using, evaluating, and managing effective learning environments, 4) professional knowledge & skill, to design, develop, apply, and evaluate learning environments enriched with educational technology within a community of practice, and 5) research, to explore, assess, synthesize, and utilize inquiry methods to enhance and improve learning outcomes. Each component integrates ethics, ensuring the responsible application of educational technology and communication processes, upholding ethical standards in theory and practice.

III. RESEARCH METHODOLOGY

This study investigates the scenario of educational technology and communications management of vocational schools in Thailand in the next decade (D.C. 2024-2034). The Ethnographic Delphi Futures Research (EDFR) is employed and is structured in the following steps: "Step 1: literature review and analysis, this phase involves studying relevant documents, theoretical concepts, and literature, followed by the analysis and synthesis of the current situation, issues, and needs regarding the management of educational technology and communication in vocational education schools in Thailand. The study is framed according to the guidelines of the AECT (2012, Online) encompassing five core standards: content knowledge, content pedagogy, learning environments, professional knowledge & skills, and research. Step 2: EFDR research technique, the target group for this research comprises 22 purposively selected experts, including: 5 senior management positions within the Office of the Vocational Education Commission, 3 university lecturers in Educational Technology and Communication, 2 educational supervisors, 5 college administrators, 6 instructors, 1 educational technology enterprises. The EDFR interview technique is employed, structured in the following steps: round 1: Interviews conducted using a semi-structured interview format, round 2: A questionnaire is drafted to encompass the conceptual framework and definitions derived from the expert interviews. Data collection is conducted using the same group of experts through the questionnaire, round 3: The questionnaire is re-administered to the same group of experts. In this round, each expert will be provided with statistical feedback reflecting the group's overall responses, including percentages, the median, and the interquartile range, along with their individual previous responses. Experts are requested to reconsider their answers and either affirm or modify them accordingly. Step 3: Report the research findings.

Figure 1: Research methodology

IV. RESULTS

The results of the analysis of the scenario of educational technology and communications management of vocational schools in Thailand in the next decade (D.C. 2024-2034) based on expert questionnaires using the EDFR Delphi technique were analyzed using SPSS. The results indicated that all items met the established evaluation criteria: 100% had a median score of at least 3.50, a difference between the median and mode not exceeding 1.00, and an interquartile range (IQR) not greater than 1.50.

Table 1: The number of future statements that meet the evaluation criteria

The scenario of educational technology and communications, Management of Vocational Schools in Thailand in the next decade (D.C. 2024-2034)	Total number of future trend questions						
	Total number of future trend questions	Level of feasibility			**Consensus of opinions**		Number of selected future trend statements
		Highest	**High**	**Moderate**	**Consistent**	**Inconsistent**	
1. Content knowledge	11	11	0	0	11	0	11
2. Content pedagogy	11	11	0	0	11	0	11
3. Learning environments	12	12	0	0	12	0	12
4. Professional knowledge and skills	21	20	1	0	21	0	21
5. Research	7	6	1	0	7	0	7
Total	**62**	**60**	**2**	**0**	**62**	**0**	**62**

Table 1 shows the number of future statements that meet the evaluation criteria which has been summarized by category as follows: 11 content knowledge, 11 content pedagogy, 12 learning environments, 21 professional knowledge and skills, and 7 research, totalling 62 statements that satisfied the statistical requirements.

Table 2: The future trends with the highest feasibility and strong consensus among experts

Question	Results							
	Mode	Median	Median-Mode	Q1	Q3	IQR	Feasibility	Consensus
Content knowledge								
1) Training in the use of basic technology tools, such as Canva or other suitable tools for creating instructional media	5	5	0	5	5	0	Highest	Strong
2) The development of knowledge on the use of technology-based media to help teachers create effective teaching materials tailored to learners	5	5	0	5	5	0	Highest	Strong
3) The development and application of technology in teaching, enabling teachers to effectively integrate technology into various subject areas	5	5	0	5	5	0	Highest	Strong
4) The development of teachers' knowledge of technology, which aids in the improvement of the teaching and learning process in the classroom and	5	5	0	5	5	0	Highest	Strong
5) Supporting teachers' access to modern teaching resources or tools that enhance the effectiveness of technology usage in education	5	5	0	5	5	0	Highest	Strong

Table 2: (continued) The future trends with the highest feasibility and strong consensus among experts

Question	Results							
	Mode	Median	Median-Mode	Q1	Q3	IQR	Feasibility	Consensus
Content pedagogy								
1) The use of technology in designing teaching activities to enhance teaching effectiveness	5	5	0	5	5	0	Highest	Strong
2) The use of appropriate technological tools for teaching specific subjects to improve teaching effectiveness	5	5	0	5	5	0	Highest	Strong
3) The creation of teaching innovations that utilize technology to enhance learning outcomes	5	5	0	5	5	0	Highest	Strong
4) The use of technology in measuring and evaluating students' learning to improve teaching and learning processes	5	5	0	5	5	0	Highest	Strong
5) The use of digital tools in creating learning activities that stimulate students' creativity	5	5	0	5	5	0	Highest	Strong
6) The selection of modern teaching media that enhance understanding and improve learning utcomes	5	5	0	5	5	0	Highest	Strong
Learning environments								
1) Teaching and learning that supports the exchange of opinions between teachers and students, contributing to the development of the teaching and learning process	5	5	0	5	5	0	Highest	Strong
2) The application of technology to create a digital environment conducive to learning	5	5	0	5	5	0	Highest	Strong
3) The use of technology to analyze student data and adjust learning activities accordingly	5	5	0	5	5	0	Highest	Strong

Table 2: (continued) The future trends with the highest feasibility and strong consensus among experts

Question	Results							
	Mode	Median	Median-Mode	Q1	Q3	IQR	Feasibility	Consensus
4) The use of technology in managing learning resources in professional subjects	5	5	0	5	5	0	Highest	Strong
5) Supporting effective learning through the use of digital technology in teaching environments	5	5	0	5	5	0	Highest	Strong
6) The development of policies and strategies for using technology in education to support learning in all aspects	5	5	0	5	5	0	Highest	Strong
Professional knowledge and skill								
1) Development and skills in using tools or software to design effective teaching and learning	5	5	0	5	5	0	Highest	Strong
2) The use of digital platforms for managing teaching, learning, and communication with students	5	5	0	5	5	0	Highest	Strong
3) Understanding the use of technology for assessment and tracking student development	5	5	0	5	5	0	Highest	Strong
4) The use of technology to create effective teaching materials	5	5	0	5	5	0	Highest	Strong
5) Understanding the application of technology in the context of teaching various professional subjects	5	5	0	5	5	0	Highest	Strong
6) The ability to design learning that is connected to real-world industry practices	5	5	0	5	5	0	Highest	Strong
7) Skills in using technology to support learning in dynamic environments	5	5	0	5	5	0	Highest	Strong

Table 2: (continued) The future trends with the highest feasibility and strong consensus among experts

Question	Results							
	Mode	Median	Median-Mode	Q1	Q3	IQR	Feasibility	Consensus
Professional knowledge and skill								
8) The creation and use of new teaching materials to develop students' professional skills	5	5	0	5	5	0	Highest	Strong
9) The development of skills in using technology for training and developing students to meet established standards	5	5	0	5	5	0	Highest	Strong
10) The ability to develop skills in using modern digital tools and technologies for teaching	5	5	0	5	5	0	Highest	Strong
11) Practical training in the use of technology in workplaces related to the profession	5	5	0	5	5	0	Highest	Strong
12) Applying technological experience from workplaces to teaching and student development	5	5	0	5	5	0	Highest	Strong
13) Learning how to use technology in real industries and conveying that knowledge to students	5	5	0	5	5	0	Highest	Strong
14) Skills in managing and adapting to the tools and technologies used in workplaces	5	5	0	5	5	0	Highest	Strong

Table 2: (continued) The future trends with the highest feasibility and strong consensus among experts

Question	Results							
	Mode	Median	Median-Mode	Q1	Q3	IQR	Feasibility	Consensus
Research								
1) Action research promoting the development of essential skills for the labor market	5	5	0	5	5	0	Highest	Strong
2) Collaboration between digital researchers, educators, and subject matter experts is crucial for developing educational technologies	5	5	0	5	5	0	Highest	Strong
3) Flexible research and development that can beimproved based on real-world usage results promotes sustainable development	5	5	0	5	5	0	Highest	Strong

Table 2 shows the data which has been summarized by category as follows: experts identified the future trends with the highest feasibility and strong consensus among experts as follows: content knowledge, 1) training in the use of basic technology tools, such as Canva or other suitable tools for creating instructional media 2) development of knowledge on the use of technology-based media to help teachers create effective teaching materials tailored to learners 3) the development and application of technology in teaching, enabling teachers to effectively integrate technology into various subject areas 4) the development of teachers' knowledge of technology, which aids in the improvement of the teaching and learning process in the classroom and 5) supporting teachers' access to modern teaching resources or tools that enhance the effectiveness of technology usage in education, content pedagogy 1) the use of technology in designing teaching activities to enhance teaching effectiveness 2) the use of appropriate technological tools for teaching specific subjects to improve teaching effectiveness 3) the creation of teaching innovations that utilize technology to enhance learning outcomes 4) the use of technology in measuring and evaluating students' learning to improve teaching and learning processes 5) the use of digital tools in creating learning activities that stimulate students' creativity and 6) the selection of modern teaching media that enhance understanding and improve learning outcomes, learning environments 1) teaching and learning that supports the exchange of opinions between teachers and students, contributing to the development of the teaching and learning process 2) the application of technology to create a digital environment conducive to learning 3) the use of technology to analyze student data and adjust learning activities accordingly 4) the use of technology in managing learning resources in professional subjects 5) supporting effective learning through the use of digital technology in teaching environments 6) the development of policies and

strategies for using technology in education to support learning in all aspects, professional knowledge and skills 1) development and skills in using tools or software to design effective teaching and learning 2) the use of digital platforms for managing teaching, learning, and communication with students 3) understanding the use of technology for assessment and tracking student development 4) the use of technology to create effective teaching materials 5) understanding the application of technology in the context of teaching various professional subjects 6) the ability to design learning that is connected to real-world industry practices | 7) skills in using technology to support learning in dynamic environments 8) the creation and use of new teaching materials to develop students' professional skills 9) the development of skills in using technology for training and developing students to meet established standards 10) the ability to develop skills in using modern digital tools and technologies for teaching 11) practical training in the use of technology in workplaces related to the profession 12) applying technological experience from workplaces to teaching and student development 13) learning how to use technology in real industries and conveying that knowledge to students 14) skills in managing and adapting to the tools and technologies used in workplaces, research 1) action research promoting the development of essential skills for the labor market 2) collaboration between digital researchers, educators, and subject matter experts is crucial for developing educational technologies 3) flexible research and development that can be improved based on real-world usage results promotes sustainable development.

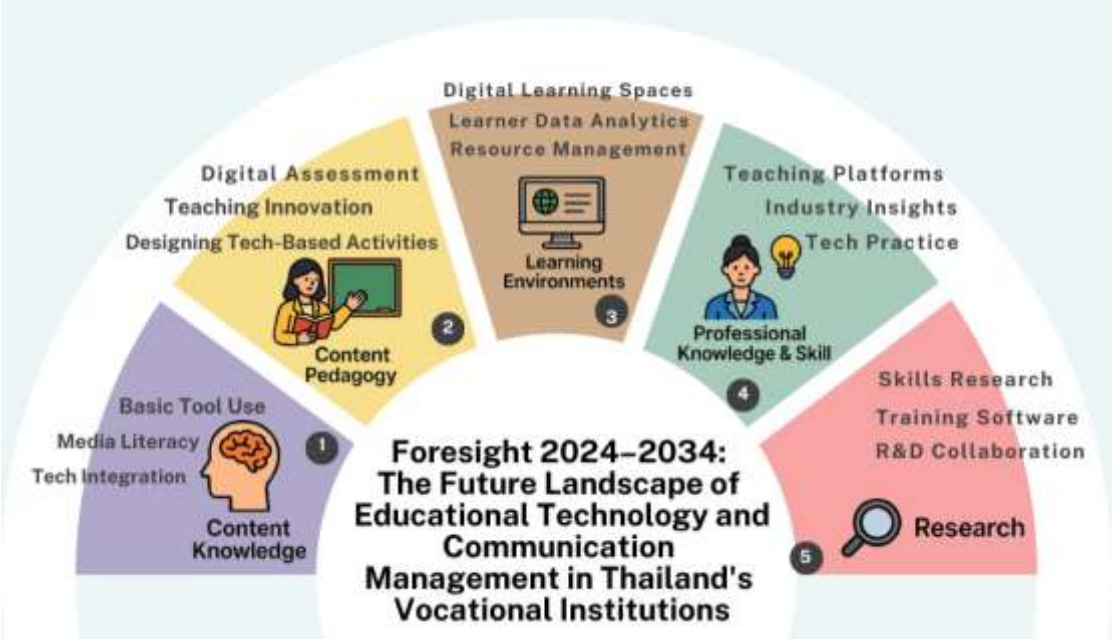

Figure 2: Foresight 2024–2034: The Future Landscape of Educational Technology and Communication Management in Thailand's Vocational Institutions

V. CONCLUSION AND DISCUSSION

The scenario of educational technology and communications management of vocational schools in Thailand in the next decade (D.C. 2024-2034) based on the analysis from the expert survey using the Delphi technique (EDFR), is summarized in the following aspects: 1) content Knowledge: experts envision the most likely future scenario, with a high level of agreement, including training on basic technology tools (e.g., Canva) to create effective teaching materials,

developing knowledge in using educational technology enables teachers to create teaching materials tailored to learners' needs, teachers' ability to apply technology in teaching across various subjects effectively improves classroom processes, and supporting teachers in accessing modern teaching resources enhances the use of technology, 2) content pedagogy: experts foresee the use of technology to design learning activities, improving teaching effectiveness, proper use of technological tools for specific subjects increases teaching quality, innovation in teaching methods, leveraging technology, enhances learning, while using technology for assessment fosters better learning outcomes, digital tools also stimulate students' creativity and help enhance understanding through modern instructional media, 3) learning environments: experts highlight the future use of technology to foster teacher-learner interaction, enhancing learning, technology helps create digital learning environments, analyze learners' data to adapt learning activities, manage learning resources effectively, and support learning through digital tools. Developing policies to incorporate technology into education ensures comprehensive learning**,** 4) professional knowledge and skills: experts emphasize the need for developing skills in using tools or software for effective lesson planning and teaching, digital platforms for managing teaching and communication with learners are key, understanding technology for assessment and tracking learner progress is crucial. Skills in creating effective learning materials and applying technology in specific vocational contexts improve teaching, teachers must be able to design learning experiences linked to real-world industries and continuously adapt to new technologies for supporting learners' evolving needs, 5) research: experts agree that action research should focus on developing necessary skills for the labor market, developing software for vocational skills training to meet market demands is essential, collaborations between digital researchers, educators, and content experts are crucial for creating sustainable educational technology, flexibility in education technology allows for continuous improvement, fostering sustainable development in vocational education.

Policy recommendations for driving the future scenario of educational technology and communications management of vocational schools in Thailand in the next decade (D.C. 2024-2034) consist of: 1) relevant agencies should enhance the potential of administrators and teachers in educational technology, including both theory and practice, with ongoing evaluation 2) national standards for technology and communication skills should be tested and used for school evaluations 3). develop an online knowledge repository on educational technology, innovations, and assessment tools accessible anytime 4) allocate budgets for teachers' self-development in educational technology, collaborating with the private sector, with evaluations to improve student outcomes 5) create a media repository with AR/VR-based learning tools across subjects for teaching preparation and real-world simulations 6) organize national and international competitions on the use of educational technology in school management and teaching 7) ensure sufficient technology infrastructure and tools for both teachers and learners 8) provide platforms for knowledge exchange on educational technology among experts, educators, and stakeholders 9) develop vocational training software aligned with industry standards to meet labor market needs 10) conduct national research to improve the use of technology in vocational education 11) develop educational apps to enhance vocational education quality and12) foster collaboration between tech researchers, educators, and content experts to create sustainable educational technologies for vocational education.

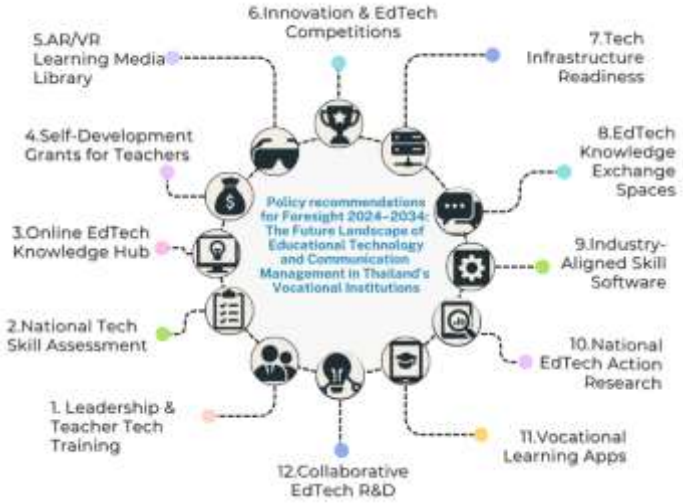

Figure 3: Policy recommendations for driving the scenario of educational technology and communications management of vocational schools in Thailand in the next decade (D.C. 2024-2034)

From the analysis of educational technology and communications management of vocational schools in Thailand in the next decade (D.C. 2024-2034), the results can be discussed through the following aspects:

1) Content knowledge: Training teachers in basic technology tools, such as Canva, to create effective teaching media is essential. This approach allows teachers to apply technology across subjects, enhancing the quality of classroom instruction. Supporting teachers' access to modern resources further improves technology usage. This aligns with the findings of Kosit (2017, p. 112) who found that teacher training and recognition of their technology skills enhance teaching practices. Similarly, Parmwong et al. (2016, p. 67) and Saengthong (2017, p. 118) emphasize the importance of ongoing training and development in educational technology for vocational educators. 2) Content pedagogy: The use of technology in designing teaching activities improves instructional effectiveness. Tools like AR and VR enhance learning experiences and foster creativity. Aliazas (2023, p. 10) indicates that educational technology positively impacts students' skills in science and technology. Similarly, Harris et al. (2016, p. 379) found that technology boosts student success and motivation by enhancing teaching methods. Experts agree that integrating technology into teaching increases efficiency and provides personalized learning. Egunjobi and Adeyeye (2024, p. 1167) highlight the role of AR and AI in transforming education, making learning environments more dynamic and accessible. Silva et al. (2023, p. 7) confirm that AR improves student performance and motivation in chemistry. 3) Learning environments: The integration of technology in teaching supports the exchange of ideas between teachers and students, enhancing learning. It creates a digital environment conducive to learning, where data analysis helps tailor learning activities, and technology aids in managing educational resources. This supports efficient learning in digital environments, aligning with Al-Abdullatif and Gameil (2021, p. 207), who found that integrating digital technology in project-based learning (PBL) improves student outcomes in higher education. Xue (2024, p. 31), further confirms that digital learning environments increase student engagement, independent learning, and learning efficiency, though excessive information and technical challenges may hinder some students' performance. 4) Professional knowledge and skills: The development of skills in using tools or software for effective lesson design, utilizing

digital platforms for teaching and communication, and understanding technology in assessing and tracking student progress are essential for enhancing teaching effectiveness. Additionally, the ability to apply technology in various professional contexts and design learning experiences linked to real-world industry work is critical. However, Wilujeng and Setiyawan (2023, p. 331) found that while digital knowledge positively affects creativity and professionalism, there is insufficient evidence to suggest that digital knowledge directly influences teaching effectiveness. In contrast, Althubyani (2024, pp. 1-24) highlighted the moderate digital competence of teachers in Saudi Arabia, with positive perceptions of digital technology use. While digital technology increases student motivation, learning experience evaluation, and communication, challenges remain regarding technology acceptance, teachers' skills, and access to digital tools. 5) Research: Study on developing essential skills for the labor market, vocational training software, and flexible educational technologies emphasizes collaboration between digital researchers, educators, and content experts. This aligns with Oarun (2021, p. 102), who found that the main challenges in technology integration in schools were collaboration and management. Key strategies for improvement included appointing responsible personnel, professional development, and building partnerships with external organizations. Similarly, Villavicencio et al. (2016, Online) highlighted the importance of user-centered design in educational technologies, successfully implemented in New York schools. Ramiel (2019, p. 492) demonstrated the significance of industry-education collaboration in developing educational technology. In addition, according to the OECD Reviews of Vocational Education and Training: Vocational Education and Training in Thailand (OECD, 2021), the development of Thailand's VET system can be significantly enhanced through the integration of educational technology and communication across five key domains: content knowledge, pedagogy, learning environments, professional knowledge and skills, and research. Educational technology contributes by improving curriculum relevance, enabling flexible instruction, supporting inclusive and interactive learning environments, strengthening teacher competencies, and facilitating data-driven research to inform policy and practice. Such integration can advance the overall quality, equity, and responsiveness of the Thai VET system.

SUGGESTION

Relevant agencies should organize training programs to build the capacity of administrators, teachers, and stakeholders in utilizing educational technology, communication tools, and AI innovations for institutional management and instructional delivery. The establishment of a centralized digital repository is recommended to support the dissemination and exchange of modern educational technology resources and innovations. This platform should enable easy access, sharing, and downloading of instructional materials. Furthermore, the appointment of technology integration specialists is essential to provide hands-on support, expert guidance, and troubleshooting in the use of educational media, digital content, and technological equipment.

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INTERNATIONAL JOURNAL of Industrial Education and Technology

THE EFFECT OF DIGITAL GAME-BASED LEARNING USING QUIZLET ON EFL STUDENTS' PERFORMANCE AND MOTIVATION

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Received: April 22, 2025 **Revised:** May 27, 2025 **Accepted:** June 13, 2025

Citation reference :
Li, J., & Phongsatha, T. (2025). The effect of digital game-based learning using QUIZLET on EFL students' performance and motivation. **International Journal of Industrial Education and Technology, 7** (1), 17-27.

ABSTRACT

This study examines the effectiveness of the digital game-based learning (DGBL) tool Quizlet in improving EFL students' learning performance, investigate its impact on learning motivation, and determines how students' motivation influences their learning outcomes while using Quizlet games. A quasi-experimental design was conducted in a Chinese higher vocational college with a sample of 67 from a population of 3,500. Throughout the 12-week experiment, the treatment group (n = 34) engaged with games on Quizlet, while the control group (n = 33) was taught using conventional methods. Quantitative data were gathered via a performance test and a 5-point Likert questionnaire measuring learning motivation. Following the use of Quizlet, the results of the independent samples t-test of the learning performance revealed significant differences in students' total scores and other skills measured ($p < .05$), except for listening ($p = .226$), following the use of Quizlet. The treatment group also reported increased learning motivation towards the use of Quizlet. Furthermore, this study proved the positive impact of learning motivation on learning performance within this DGBL context, indicated by a relatively high R^2 value of .504. These findings highlight the effectiveness and importance of DGBL in EFL learning. Future research should increase sample diversity to assess generalizability, employ a mixed approach incorporating qualitative analyses and expand beyond the focus of the ARCS Model by integrating theories like Self-Determination Theory (SDT).

Keywords: Digital game-based learning, Quizlet, EFL Learning, Learning performance, Learning motivation

I. INTRODUCTION

With the ongoing scientific and technological revolution, digital technology has become an increasingly significant driving force that is fundamentally changing and reshaping the field of education. This evolution is exemplified by the 2024 World Digital Education Conference in Shanghai, China, which highlighted how digital technologies are revolutionising traditional teaching approaches. There is no denying that the application and advancement of digital technology have opened up new possibilities for education (Xu et al., 2020, pp. 877-904).

In the realm of English as a Foreign Language (EFL) learning, a variety of digital technologies and tools have been adopted to complement the learning environments, among which digital games seem to be one promising option. As a form of fun and play, digital games can powerfully engage students, and digital game-based learning (DGBL) has been identified as an approach to putting games and learning together (Prensky, 2005, pp. 97-122). References have indicated a growing trend of research interest in DGBL since 2000. Many studies have confirmed that the implementation of DGBL has the potential to enhance students' self-efficacy, learning motivation, and learning performance (Berns et al., 2016, pp. 1-23; Chen & Lin, 2016, pp. 171-186; Eltahir et al., 2021, pp. 3251-3278).

The current generation of college students has been described as "digital natives" - a term popularised by Marc Prensky (2001b, pp. 1-6). These individuals have been immersed in digital technologies since birth, interacting with countless digital devices emblematic of the modern era. Despite the widespread ownership and frequent use of smartphones among college students, these gadgets are commonly restrained in traditional classroom settings, where educators deem them disruptive to academic focus (Cárdenas-Moncada et al., 2020, pp. 64-78). Moreover, the characteristics of today's EFL students in higher vocational institutions have posed significant challenges for EFL learning. Admittedly, their overall language proficiency is inferior to that of university undergraduates. To worsen the situation, this group of students lack interest and motivation in learning English as they fail to recognise the importance of English in this highly globalised society. Therefore, they tend to be a passive audience rather than active participants, showing reluctance to engage in class activities.

To address the problem, this research aims to determine the effectiveness of using the DGBL tool Quizlet in improving EFL students' learning performance, to explore the impact of implementing Quizlet on students' learning motivation and to identify the influence of students' motivation when using Quizlet games on their performance in EFL learning.

II. LITERATURE REVIEW

The term DGBL, proposed and popularised by Marc Prensky in a book by the same name Aguilera and de Roock (2022, Online), integrates serious learning with interactive entertainment to create an engaging and enjoyable educational medium. Prensky firmly believed that DGBL would be taken for granted as a way of learning for current and future generations (Prensky, 2001a, pp. 1-5). Many studies examining the impact of DGBL on learning from different perspectives, including psychology, cognition, and learning environment, have confirmed Prensky's ideas. Essentially, DGBL is regarded as a novel approach to learning that aims to reposition education in a changing environment (Pivec, 2007, pp. 387-393), which can better engage learners but

also deepen their understanding of the learning content with improved learning outcomes and positive attitudes toward its use (Chen & Lin, 2016, pp. 171-186). Within the context of EFL, recent studies have demonstrated that DGBL applications or tools are effective for second language acquisition. In a scoping review study, Hung et al. (2018, pp. 89-104) systematically analysed 50 studies from 2007 to 2016. The findings indicated that most of these studies exhibited favourable learning outcomes, with affective or psychological improvements being the most commonly observed outcomes, followed closely by gains in language proficiency. The results of a quasi-experiment conducted by Kazu and Kuvvetli (2023, pp. 13541-13567) also showed improvement in students' test scores with the help of a DGBL tool. Motivation, derived from the Latin "movere" (to move), represents the internal forces that activate and direct goal-oriented behavior. Despite varying conceptualizations across disciplines, motivation is generally understood in psychology as the process that initiates and maintains goal-directed activities, encompassing the factors that influence both an individual's objectives and their persistence in pursuing them (Keller, 2010, pp. 267-295; Ryan & Deci, 2000, pp. 54-67; Schunk et al., 2014, pp. 1-33). In learning, motivation has long been considered one of the most complex and crucial components that determine students' achievements (Cheng & Dörnyei, 2007, pp. 153-174; Guo et al., 2015, pp. 368-384; Huang et al., 2006, pp. 243-259). Li and Pan (2009, pp. 123-128) pointed out that motivation is a significant reason for students' learning performance among other influential factors. Findings of relevant research also indicated that students' motivation had a significantly positive impact on their learning performance and outcomes in a DGBL setting (Chen & Tu, 2021, pp. 1-16; Lin et al., 2017, pp. 123-127). The ARCS Model of Motivation, developed by Keller (1987, pp. 1-7), is a methodical and systematic approach to identifying and dealing with motivational issues in instructional design and teaching. The model represents the four major constructs for people to become and remain motivated: Attention, Relevance, Confidence, and Satisfaction. Attention is an element of motivation and also a prerequisite for learning. Relevance meets the personal needs or goals of the learner to create a positive attitude. Confidence helps learners believe that they will succeed, while satisfaction finally reinforces the accomplishments with rewards (Keller, 1987, pp. 1-7). Over 30 years, it has become one of the most widely adopted frameworks for studying instructional games. Researchers worldwide have incorporated it into teaching design and assessment through questionnaires, using it to assess the effectiveness of instructional intervention in sustaining or increasing learners' motivation (Guo et al., 2015, pp. 368-384; Hao & Lee, 2021, pp. 1101-1114; Huang et al., 2014, pp. 631-641).

Based on the conceptual framework, seven hypotheses were developed to achieve the research objectives.

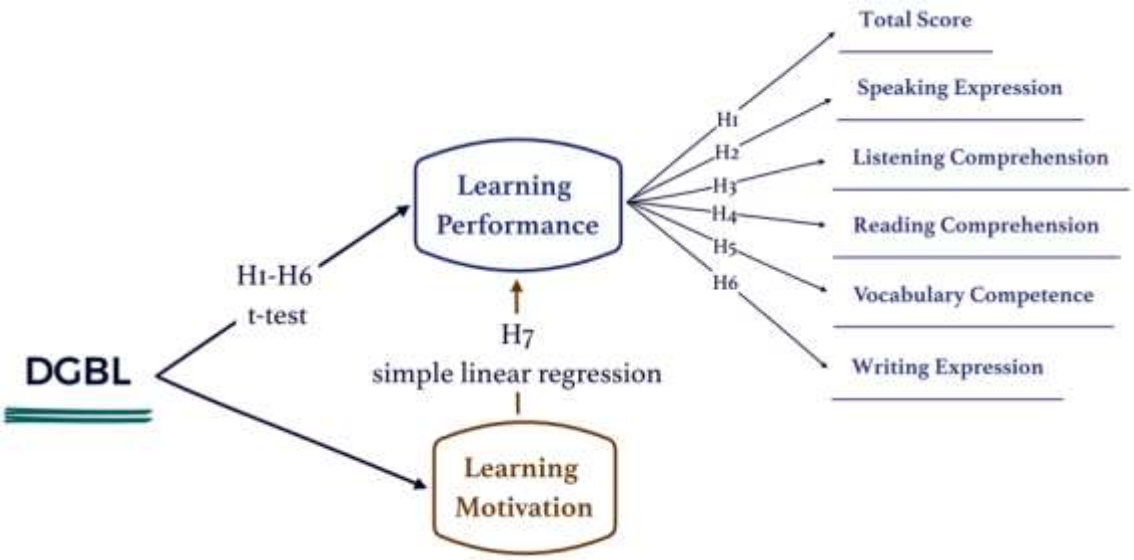

Figure 1: Conceptual framework

Hypothesis 1: The total score of students taught with Quizlet is higher than those taught traditionally.

Hypothesis 2: The speaking expression score of students taught with Quizlet is higher than those taught traditionally.

Hypothesis 3: The listening comprehension score of students taught with Quizlet is higher than those taught traditionally.

Hypothesis 4: The reading comprehension score of students taught with Quizlet is higher than those taught traditionally.

Hypothesis 5: The vocabulary competence score of students taught with Quizlet is higher than those taught traditionally.

Hypothesis 6: The writing expression score of students taught with Quizlet is higher than that of those taught traditionally.

Hypothesis 7: Students' learning motivation affects their learning performance after using Quizlet.

III. RESEARCH METHODOLOGY

Research Design

This study employed two quantitative methods to address the research questions: a quasi-experiment for 12 weeks and a 5-point Likert scale questionnaire. Quizlet was employed as the digital game-based learning tool, a versatile mobile and web-based study tool which allows users to learn through flashcards and game-based activities, including Match, Classic Live, and Blast in its latest version. Two first-year classes were selected and assigned as treatment (learning with Quizlet) and control (learning traditionally) groups, with prior academic test scores confirming comparable English proficiency. After the treatment, post-test scores

were analysed using independent samples t-tests. The questionnaire based on the ARCS Model was answered by the treatment group to measure learning motivation through descriptive statistics. A simple linear regression then examined the impact of learning motivation on performance.

Population and Sample

This study was conducted at a higher vocational college in Hangzhou, Zhejiang Province, China. The population under investigation comprised all first-year non-English majors, with a total of 3,500 students. The researchers used purposive sampling. Two freshman classes from the Sino-American Joint Program of E-commerce, rather than individual samples, were selected, as students were already assigned to classes by the institution. The sample size was 67 (control group n = 33; treatment group n = 34), which met the threshold to guarantee sufficient statistical power for the analyses. Aged from 18 to 20 years old, the participants shared similar English learning experiences, demonstrated comparable English language proficiency in High School English Proficiency Test and had a relatively high acceptance of using digital technologies in learning.

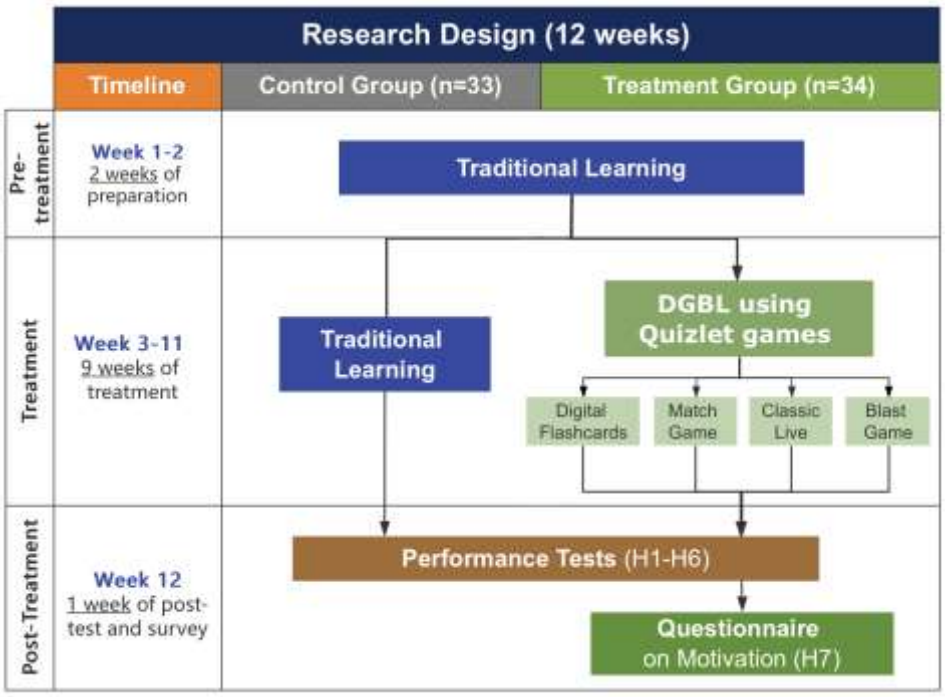

Figure 2: Research design

Figure 3: Learning plan and treatment flow

Measurement Tool

Performance tests were employed to evaluate the learning outcomes of the participants for the initial research purpose. The post-test, functioning as the course's final examination, was developed in accordance with the institution's rubrics and guided by China's Standards of English Language Ability (CSE). The performance test assessed the following variables: total score, speaking skill, listening comprehension, reading comprehension, vocabulary competence, and writing skill. The total score was measured initially to determine whether the use of Quizlet improved students' learning performance. Further research of the remaining variables was then conducted to ascertain which elements were most beneficial.

The second instrument was a 5-point Likert scale questionnaire which comprised two sections. The first part aimed to collect essential demographic information, including age and gender. The second segment focused on students' learning motivation towards the utilisation of Quizlet. With 16 items altogether, this part was adapted from the ARCS Model of Motivation by John Keller (2010, pp. 267-295) and somewhat adjusted to address the second and third research objectives. The validity was assessed by three experts based on IOC with strong agreement. A pilot study was conducted to ensure its reliability.

IV. RESULTS

Independent Samples *t*-Tests

An independent samples t-test was conducted to compare learning performance outcomes between the treatment and control groups. As shown in Table 1, the treatment group exhibited higher mean scores and lower standard deviations across all variables, suggesting both improved performance and greater consistency in outcomes. Statistically significant differences favoring the treatment group were found for the total score ($p = .007$, $d = .612$), speaking expression ($p = .002$, $d = .737$), reading comprehension ($p = .041$), vocabulary competence ($p = .007$), and writing expression ($p = .006$, $d = .627$), with all p-values falling below the .05 threshold. Effect sizes for the total score, speaking, and writing were medium (Cohen's $d > 0.5$), whereas reading comprehension and vocabulary competence showed smaller effects. These results led to the support of the research hypotheses for the five aforementioned variables. Listening comprehension proved to be the only exception, with no significant difference detected between treatment and control groups. The p-value of .266 exceeded the predetermined .05 significance threshold, and the effect size was small. Consequently, the hypothesis 3 was not supported, indicating comparable performance between groups in this domain.

Table 1 Comparison of Students' Learning Performance between Control and Treatment Groups

Variables	Groups	Mean	t-value	p-value	Effect Size	SD
Total Score (100%)	Treatment	81.32	5.975	2.505	.007	.612
	Control	76.23	10.199			
Speaking (15%)	Treatment	13.01	.515	3.014	.002	.737
	Control	12.5	.848			
Listening (10%)	Treatment	8.24	1.539	.627	.266	.153
	Control	7.97	1.912			
Reading (30%)	Treatment	25.82	2.329	1.786	.041	.432
	Control	24.36	4.197			
Vocabulary (30%)	Treatment	21.97	3.810	1.706	.046	.417
	Control	20.21	4.601			
Writing (15%)	Treatment	12.28	1.226	2.564	.006	.627
	Control	11.18	2.164			

Descriptives of the Questionnaire

The treatment group comprised 13 males and 21 females, with a mean age of between 18 and 20 years. Descriptive statistics were calculated for the four motivation constructs measured in this study. As shown in Table 2, all constructs demonstrated high mean scores (m = 4.48 to 4.61), signifying predominantly positive motivation levels across all domains. Satisfaction exhibited the highest mean score (m = 4.61) with the lowest standard deviation (SD = .657), suggesting it is the most consistently positive construct with the least variation among respondents. The overall mean score was also high (m = 4.53), indicating a high level of agreement.

Table 2 Students' Motivation Levels Based on Questionnaire Responses

Constructs	Mean	SD	Description
Attention	4.49	.869	Agree
Relevance	4.54	.749	Strongly Agree
Confidence	4.48	.730	Agree
Satisfaction	4.61	.657	Strongly Agree
Total	4.53	.755	Strongly Agree

Simple Linear Regression

To examine the final hypothesis, researchers performed simple linear regression with total scores of the performance test as the dependent variable and motivation scores (questionnaire total means) as a covariate. The model yielded a strong statistical significance ($p < .001$) and a coefficient of determination value of 0.504, explaining 50.4% of the variance in performance - a notably strong effect in educational technology and second language acquisition research. confirming motivation as a reliable predictor of learning performance and leading to rejection of the null hypothesis.

Table 3 Predictive Relationship Between Students' Motivation and Learning Performance

Model	R	R^2	F	*p*-value
1	.710	.504	32.5	< .001

V. CONCLUSION AND DISCUSSION

This study investigated the effectiveness of Quizlet as a digital game-based learning instrument in EFL instruction. The quasi-experiment design focused on three primary aspects: learning performance, student motivation, and the link between motivation and performance. The independent samples t-test results indicated substantial disparities in students' performance. All variables, except for listening comprehension, exhibited p-values below the .05 threshold, showing significant improvement in the treatment group. This suggests that students learning with Quizlet outperformed those learning via conventional methods in total score, speaking expression, reading comprehension, vocabulary competence, and writing expression. While Quizlet appears to benefit overall performance as well as most skills of EFL learning, its impact on listening comprehension may be relatively limited. The findings were consistent with the majority of studies, including those by Kazu and Kuvvetli (2023, pp. 13541-13567) and Li (2021, pp. 1-12), which also applied the DGBL approach. However, this study could not reproduce the same positive effect of Quizlet on listening comprehension as asserted in other related studies, like Dizon (2016, pp. 40-56) and Hwang et al. (2017, pp. 26-42). The descriptive data of the questionnaire revealed consistently high motivation scores across all measured constructs, particularly with the total mean surpassing 4.6 on a 5-point scale. These findings provide compelling evidence that Quizlet positively influenced students' learning motivation with the EFL learning context, aligning with the conclusions of numbers of previous studies (Berns et al., 2016, pp. 1-23; Chen & Lin, 2016, pp. 171-186; Eltahir et al., 2021, pp. 3251-3278; Li, 2021, pp. 1-12; Tsai & Tsai, 2018, pp. 345-357). The significant variance in learning outcomes explained by motivation (R^2 = .504) indicates a remarkably strong relationship in educational contexts, where learning is typically influenced by numerous complex factors. This finding serves to reinforce the conclusions of previous DGBL research (Chen & Tu, 2021, pp. 1-16; Li & Pan, 2009, pp. 123-128; Lin et al., 2017, pp. 123-127), confirming that motivation serves as a powerful predictor of performance within game-based learning environments.

The absence of a notable difference in listening comprehension, as indicated by the non-significant p-value of .266, may be ascribed to several factors. First, the inherent characteristics of Quizlet primarily emphasise visual and text-based interaction. Despite the inclusion of a pronunciation option in flashcards, the design of this study focused on its gaming features (e.g. Match Game, Blast and Classic Live), which may not directly address the complex cognitive processes involved in listening comprehension. In contrast to vocabulary or reading, listening comprehension requires multiple cognitive processes, including phonological awareness and working memory, which Quizlet may not adequately replicate (Vandergrift & Baker, 2015, pp. 390-416). Second, the duration or intensity of the intervention might have been inadequate to promote remarkable improvements in listening, a skill that typically requires extended exposure to authentic spoken input (Chang & Millett, 2016, pp. 349-362).

SUGGESTION

This study is still subject to certain limitations. It employed a rather homogeneous sample and a questionnaire with certain constraints. The study didn't address potential cofounding variables such as students' prior experience with digital game-based tools, their engagement outside of class, or teacher involvement, all of which could influence learning outcomes. For future research investigating DGBL in EFL contexts, researchers should expand participant diversity in size, academic backgrounds, and proficiency levels to better determine Quizlet's effectiveness across broader populations to increase the generalizability of the findings. Additionally, incorporating mixed-methods approaches with qualitative elements (interviews, reflective journals) would provide deeper insights into student experiences with DGBL tools. Research should also consider moving beyond the ARCS Model's focus on external motivators to explore intrinsic motivation through frameworks like Self-Determination Theory, which examines intrinsic vs. extrinsic motivation, autonomy, competence, and relatedness as deeper drivers of engagement.

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INTERNATIONAL JOURNAL of Industrial Education and Technology

USING EYE-TRACKING TECHNOLOGY TO ASSESS CONSUMER INTEREST IN THE GRAPHIC DESIGNS ON VITAMIN WATER PACKAGING

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Received: May 13, 2025 **Revised:** June 10, 2025 **Accepted:** June 13, 2025

Citation reference :
Kuntaros, S., Sornkhieo, W., Bubhawong, R., Patchanee, N. & Satwecg, S. (2025). Using eye-tracking technology to assess consumer interest in the graphic designs on vitamin water packaging. **International Journal of Industrial Education and Technology, 7** (1), 28-45

ABSTRACT

This research aims to assess how eye-tracking technology can be applied to identify which graphic design elements on vitamin water packaging most effectively capture consumer attention and influence their visual behavior. The study simulated a shopping scenario in a laboratory setting. Six different packaging styles (AOI1-6), each featuring a variety of elements such as styles, images, and logos, were tested. The participants were 30 male and female consumers aged between 20 and 30 years old, selected using purposive sampling. Viewing behavior was recorded using Tobii Pro Glasses 3, focusing on the number of fixations and duration of fixation. The results indicated that AOI 1 -featuring a vertical logo and a realistic image-received the highest attention in terms of both the number of fixations and the duration of fixation, with averages of 22 and 21.786 seconds, respectively. ANOVA results showed that the six styles were significantly different ($p < .001$). Additionally, the heatmap test results showed that the center position on the simulated shelf received the most attention, with dark red representing the longest viewing duration. While the left side could still attract a considerable amount of attention, the right side received the least. These findings can be used as a guide to design vitamin water packaging graphics that more effectively capture consumer attention and support purchasing decisions.

Keywords: Vitamin water, Graphics on packaging, Packaging design, Eye-tracking technology

I. INTRODUCTION

The vitamin water market is growing rapidly today due to health-oriented consumer interest and a preference for nutritious products. In the aftermath of the COVID-19 pandemic, Thai people have become more health-conscious. Therefore, vitamin water has emerged as a popular option that aligns well with current health trends. It is classified as a functional drink with high growth potential in the Thai market, supported by economic expansion and a continuous increase in consumer demand Entrepreneurs need to differentiate their products, especially by making the packaging stand out and look credible, which is an important strategy for success in the market (Pringplerd, 2022, pp. 1-2).

Packaging is one of the key factors influencing consumers' purchasing decisions. This is especially true for health-related products such as vitamin water, where consumers pay close attention to nutritional information on the label, as well as graphic elements on the packaging. Features such as color, imagery, and logos help create brand recognition (Vijitsombat, 2021, p. 34). Packaging design needs to take into account both utility and aesthetics in order that the product stands out, differentiates itself from the competition, and meets the needs of the target audience.

Eye-tracking technology has been increasingly used in packaging design research as it enables researchers to accurately identify consumer points of interest, such as the number of fixations and fixation duration. These metrics provide more in-depth behavioral data than conventional questionnaires. Research by Varela et al. (2014, pp. 701-710) shows that the branding area on packaging is the most visually appealing for consumers. Eye-tracking data can help designers place art elements more purposefully and efficiently. However, there is a lack of studies that link eye-tracking data to deeper insights into purchasing decisions, which is necessary to comprehensively understand consumer behavior.

In light of these considerations, the researcher employed eye-tracking technology as a tool to examine and quantify consumer visual interest in the graphic designs of vitamin water packaging. Conducted in a simulated experimental environment, the study focuses on identifying the graphic elements on vitamin water packaging that are most visually appealing and analyzing the relationship between visual behavior and purchasing decisions. The findings aim to provide insights into vitamin water packaging design strategies that can enhance consumer appeal. Additionally, they also serve as a practical guide for entrepreneurs seeking to develop vitamin water packaging styles that are both competitive and sustainable in an increasingly dynamic market.

II. LITERATURE REVIEW

The use of eye-tracking technology continues to gain attention in the study of consumer behavior and packaging design. Nemergut and Mokrý (2020, pp. 371-378) found that the use of realistic fruit images on juice packaging can stimulate greater consumer interest than the use of drawings. Mehta et al. (2023, pp. 8845-8860) applied eye-tracking technology together with facial expression analysis via a high-resolution webcam to assess consumers' interest in orange juice packaging. It was found that nutritional information received the most visual attention and was significantly linked to the emotional reactions of consumers. Meanwhile, Tonkin et al. (2011, pp. 1-8) compared consumers' visual behavior in real and simulated environments, concluding that simulated experiments closely replicate real consumer behavior while also effectively reducing research costs. Similarly, Szocs and Lefebvre (2016, pp. 152-159) pointed out that imagery is the most important element influencing both attention and purchase decisions. Supporting this, Kattibut (2022, p. 87) found that branding and product descriptions are important elements that help build credibility and motivate purchase decisions in the context of vitamin water products.

Previous studies have demonstrated that graphic elements on packaging, including logos and product information, significantly influence customer interest. Moreover, the utilization of eye-tracking technology can yield insights into viewing behaviors associated with purchasing decisions. Building on this knowledge, the present study aims to establish a framework for identifying Areas of Interest (AOI) on vitamin water packaging to comprehensively examine the correlation between viewing behavior and purchasing decisions. The number of fixations, duration of fixation, and the graphic styles that garner the most attention will be analyzed. The findings are expected to result in the development of packaging design guidelines that effectively align with the expectations and behaviors of the target audience, thereby enhancing appeal in a competitive market.

III. RESEARCH METHODOLOGY

Conceptual Framework

This research is an experimental investigation aimed at evaluating consumer interest in graphic styles on vitamin water packaging, using eye-tracking technology. The conceptual framework guiding this research is outlined below, as illustrated in Figure 1.

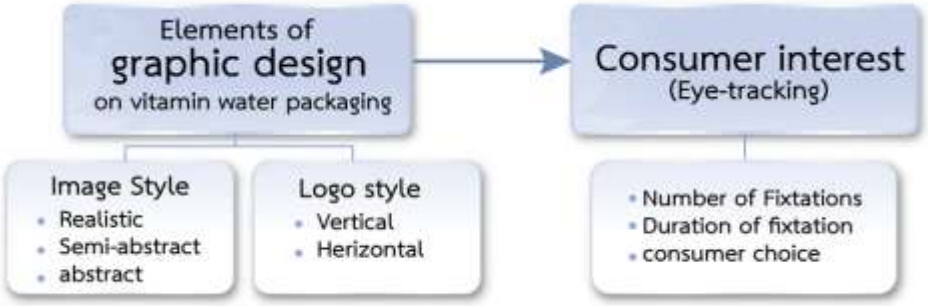

Figure 1: Conceptual framework

Population and Sample Groups

The age range of 20-30 years was selected based on prior research by Thienthong (2021, p. 36), which found that this group exhibited significantly higher intentions to repurchase and increase future consumption of vitamin water compared to other age groups, as confirmed by Bonferroni pairwise comparisons. Additionally, participants in this age range are known to have more stable eye movement behavior than older individuals, which aligns with the experimental requirement for participants with normal visual function in eye-tracking studies. Therefore, this age group represents both a relevant consumer segment and a methodologically appropriate sample for the study.

The sample consisted of male and female vitamin water drinkers aged 20-30 years. Purposive sampling was used to select 30 participants. The inclusion criteria required that all participants had previously purchased or drunk vitamin water, regardless of the brand. The sample size was calculated through power analysis, using a power level of 0.80, an effect size of 0.5 (Cohen, 1988, pp. 77-83), and a significance level of 0.05, calculated using G*Power software. The analysis indicated a required sample size of 27 participants. To account for potential loss of participants during the experiment, three more participants were added, resulting in a final sample size of 30 participants.

Experiment

1) The researcher designed six different graphic styles for vitamin water packaging (AOI1-6) to test participant interest. These designs were displayed against a white background with a refrigerator backdrop to simulate a realistic shelf-viewing environment within a laboratory setting. The placement of the packaging designs was rotated among left, center, and right positions so that the placement position of the simulated vitamin water bottle on the screen did not influence the attention of the participants. Each image was presented for 3 seconds.

2) Before the experiment was performed, the participants in the experimental group completed a color blindness test by looking at an Ishihara test strip on a monitor with a web browser simulator, provided by the researcher. Test takers had to achieve a 100% score to proceed to the next step. The test took about 30 seconds to complete.

3) After being tested for color blindness in step 2, the participants were instructed to wear the Tobii Pro Glasses 3 eye-tracking device. To prevent the device and its connecting cable from becoming entangled with the participant's face or hair around the ears, participants were asked to hold the recording unit-connected to the end of the glasses' leg-in one hand and rest it on their lap for the duration of the experiment. The researcher then performed a one-point calibration by holding a calibration card at a distance of 50-100 centimeters from the participant. After that, participants were asked to look at the screen to begin the eye-tracking evaluation.

4) Once all the images had been viewed, participants were instructed to remove the eye-tracking glasses and complete the interest assessment form. This assessment form focused on their interest in the graphic styles presented on the vitamin water packaging.

5) The collected data were analyzed to evaluate consumer interest in each graphic style. The results were then summarized and discussed based on a comparison of two key eye-tracking metrics: the average number of fixations and the average fixation duration (measured in milliseconds).

Research Tools

1) The research tools comprised the Tobii Pro Glasses 3 eye-tracking device, and a screen used to display the vitamin water packaging models. The screen was a 27-inch LG UHD 4K monitor (model 27UP600-W) with a 16:9 aspect ratio and a display resolution of 1920 x 1080 pixels. The Tobii Pro Glasses 3 eye-tracking device is shown in Figure 2.

Figure2 : Tobii Pro Glasses 3 eye- tracking device (a) and data recording device (b)

2) The survey consisted of both multiple-choice questions and open-ended questions, allowing respondents to express their opinions in detail. Instrument quality inspection was performed by qualified experts in measurement and evaluation. The item validity analysis yielded a score of 0.90, which exceeded the minimum threshold of 0.50, indicating that the instrument had a "valid" level of accuracy.

Data analysis

1) Consumer interest data on vitamin water packaging were analyzed to identify which graphic styles were most frequently viewed, based on the number of fixations. Each of the six packaging styles (AOI1-6) were presented in different positions on the monitor, resulting in 12 images viewed by each participant. The total number of fixations for each AOI across all 30 participants was recorded. These values were then averaged to determine the overall number of fixations for each of the six packaging styles.

2) Consumer interest data were also analyzed to determine which graphic styles on vitamin water packaging received the longest viewing time, measured by duration of fixation in milliseconds. The duration of fixation was recorded for each area of interest (AOI1-6) displayed on the monitor. The average fixation duration for each AOI was calculated to summarize the overall viewing time for each packaging style. The first and second analyses employed one-way analysis of variance (ANOVA) to test for significant differences in means. The independent variable was the graphic style of the vitamin drinking water packaging, classified into six styles (AOI1-6), while the dependent variables were the number of fixations and the duration of fixation.

3) To analyze whether graphic styles on vitamin water packaging influence consumer purchasing decisions, frequency distribution analysis was used. This analysis examined the consistency between the duration of visual attention on each graphic style and purchasing decisions. Specifically, the study investigated whether the packaging style that received the longest viewing time corresponded with the participants' self-reported choice in the post-experiment assessment. Based on the consistency between participants' visual attention and their questionnaire responses, the analysis aimed to determine whether the area of interest (AOI1-6) that received the most attention—on the most visually distinct packaging style-also influenced purchasing decisions. The proportion of participants who chose a specific graphic style as their preferred choice was compared to the eye-tracking data to assess its influence on purchase decisions. To support this analysis, dummy variables were created using binary values (0 and 1), allowing the data to be interpreted on a nominal or ordinal scale, as follows:

3.1 If a participant chose a graphic style on the vitamin water packaging as the one that most influenced their purchasing decision, and that selection was consistent with the packaging style they viewed for the longest duration, a value of 1 was assigned.

3.2 If a participant selected a graphic style on the vitamin water packaging as the one that most influenced their purchasing decision, but this selection was inconsistent with the style they viewed for the longest duration, a value of 0 was assigned. The results were analyzed using a one-proportion Z-test, which assessed whether the proportion of participants whose purchase decisions aligned with the graphic style they viewed the longest differed significantly from chance. Specifically, the test compared participants who selected the graphic style that corresponded with the one they looked at the longest (consistent, coded as 1), and participants whose chosen style did not correspond with their longest viewing time (inconsistent, coded as 0). The hypotheses for the test were defined as follows: Null hypothesis (H_0): $p \leq 0.5$-The proportion of consistent responses is 50% or less (no effect); Alternative hypothesis (H_1): $p > 50\%$-The proportion of consistent responses is greater than 50% (indicating an effect). The test was conducted at a significance level of $\alpha = 0.05$.

IV. RESULTS

The graphic design of the vitamin water packaging, developed for consumer interest testing using eye-tracking technology, focused on specific Areas of Interest (AOIs). The researcher created six packaging styles (AOI1-6), each incorporating distinct graphic elements centered around imagery. The central visual component was a background scene featuring mountains, trees, and the sky. These elements were intentionally chosen to reflect key associations: Mountains and trees conveyed naturalness and freshness, which are selling points of vitamin water. The sky conveyed purity, clarity, and relaxation, aiming to resonate with consumers seeking refreshment from daily fatigue. The color scheme for this case study included blue, green, and white tones: Blue represents freshness and safety, green represents naturalness, and white represents the purity of vitamin water. Three distinct image styles were developed: 1) Realistic: A photograph-like image using natural light and shadows to mimic how the human eye perceives the scene; 2) Semi-abstract: Based on the realistic image but with distorted details and sharp mountain lines to create a novel and visually stimulating effect; 3) Abstract: A more stylized version using freeform shapes and simple colors to express the concept artistically. In terms of product information, the label prominently displays the product name- "Vitamin Water" -in both Thai and English. A sans-serif font was selected for the English text to emphasize stability and modernity, with the straight lines instilling confidence in the quality and cleanliness of the water and its vitamins, which are beneficial for the body. The Thai text was styled with a headless font to maintain visual consistency with the English font and ensure suitability for the target audience, enhancing readability from a distance. In this study, the key product descriptor was "Vitamin B", presented in blue to convey the cleanliness of vitamin water products and their vitamins. All six packaging designs (AOI1-6) were based on these design concepts in various combinations, as shown in Table 1.

Table 1: Styles of graphic elements on vitamin water packaging (AOI1-6)

AOI	Elements of vitamin water packaging	Mock up	Logo style		Image style		
			Vertical logo	Horizontal logo	Realistic image	Semi-abstract image	Abstract image
1			✓		✓		
2			✓			✓	
3			✓				✓
4				✓	✓		

Table 1: (continued) Styles of graphic elements on vitamin water packaging (AOI1-6)

AOI	Elements of vitamin water packaging	Mock up	Logo style		Image style		
			Vertical logo	Horizontal logo	Realistic image	Semi-abstract image	Abstract image
5				✓		✓	
6				✓			✓

Based on the results presented in Table 1, the graphic design styles of the vitamin water packaging were displayed on a screen in a simulated environment that closely resembled a real-world setting. Each image of the vitamin water packaging was placed on a virtual mock-up structure, with a screen backdrop designed to resemble the appearance of products on the shelf of a refrigerator in a convenience store. The six packaging styles were arranged for display in sets of three per screen page. The positions of the images (left, center, and right) were rotated across the pages. Participants were given clear on-screen instructions that read: "The image will appear on the screen for 3 seconds. You can look freely at a total of 12 images." The images displayed on the screen automatically changed in sequence until the viewer had seen all 12 images. The sequence and layout of the image presentations used to assess interest in the graphic styles of the vitamin water packaging are shown in Figure 3.

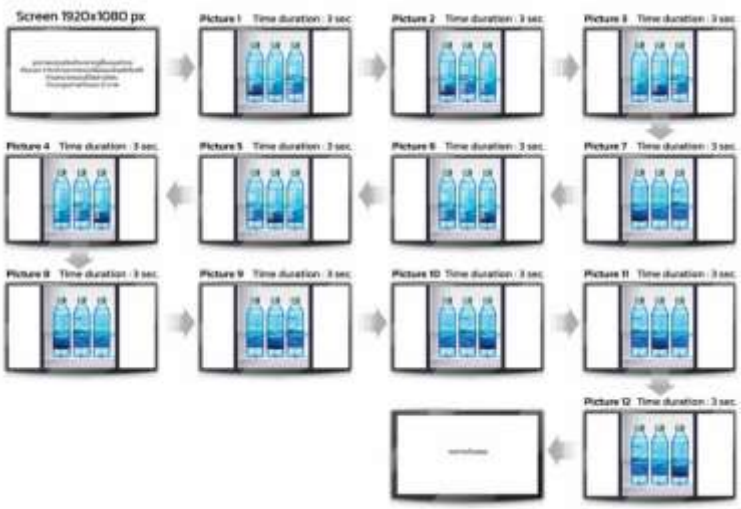

Figure3 : The sequence of the presentation of graphic styles on vitamin water packaging

The experiment in this research was designed to be consistent with the experimental conditions specified by the researchers. It was conducted in a controlled laboratory environment with a fixed experimental duration to reduce the influence of external distractions on the detection of eye movements, as shown in Figure 4. The location and installation characteristics of the data collection equipment, as well as the positioning of the participants, were also carefully considered.

Figure 4: Example of the positioning and setup of the data collection device in relation to the participant.

The researcher assessed the results of the experiment to determine consumer interest in the visual design of vitamin water packaging using eye-tracking technology. Figure 5 depicts the interface of the eye-tracking test conducted with testers using the Tobii Pro Glasses 3 Controller program.

Figure 5: Interface of the eye-tracking test conducted using the Tobii Pro Glasses 3 Controller program

Figure 5 shows an example of the analytical output for the number of fixations and duration of fixation across six graphic styles of vitamin water packaging (AOI1-6) from 30 participants (n = 30). The researcher analyzed the results by inputting relevant data into the Tobii Pro Glasses 3 Controller program, as shown in the figure. (1) Gaze Overlay: This is represented by red circles that show where the participants focused their visual attention. In the image, the gaze overlay appears on one of the vitamin water packages, with the diameter of the red circle covering specific graphic elements, signaling the participant's visual focus on that area. (2) Area of Interest (AOI): The AOIs were pre-defined by the researcher to analyze the eye-tracking test results of each participant. In this research, each graphic style of the simulated vitamin water bottle packaging was assigned to one of the distinct AOIs (AOI1-6), as previously shown in Table 1. (3) Time Interval Selection: The program was set to evaluate visual attention within a 3-second window per image, matching the experimental design. The Tobii Pro Glasses 3 Controller program was then used to calculate and display

eye-tracking metrics, which were then analyzed to assess consumer interest in each packaging style. The results of this data analysis are as follows:

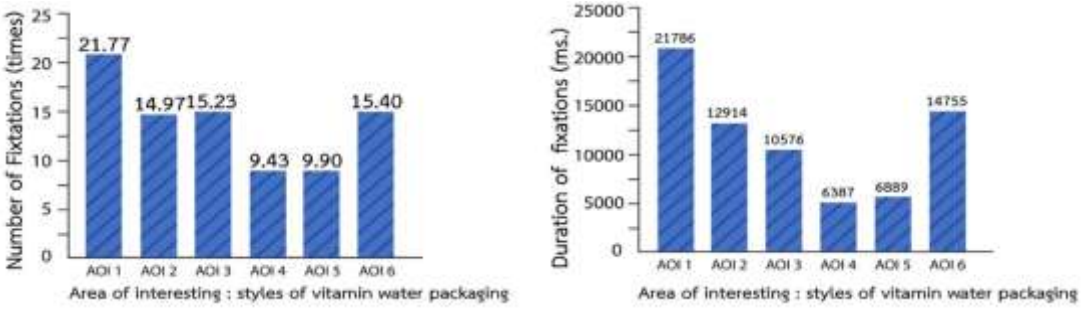

Figure 6: Comparative analysis of consumer interest in graphic styles on vitamin water packaging

From Figure 6 (left), the results of the comparative analysis of consumer interest data on vitamin water packaging are presented to identify which graphic styles consumers "looked at the most," based on the number of fixations recorded across six styles (AOI1-6). The analysis of the average number of fixations per person revealed that the averages obtained were decimal fractions rather than whole numbers, or integers. Therefore, the researcher rounded up the decimal fractions with a value of 0.5 or more to 1, and rounded down those below 0.5 to 0. The findings indicate that Style 1 (AOI 1)-featuring a vertical logo with a realistic image style-received the highest average number of fixations, at 22 times per participant. In contrast, Style 4 (AOI 4)-which included a horizontal logo with a realistic image style-received the lowest average number of fixations, at 9 times per participant.

Figure 6 (right) presents the results of a comparative analysis of consumer interest data on vitamin water packaging, aiming to identify the graphic styles that consumers "looked at the longest," based on the duration of fixations measured in milliseconds. The findings indicate that Style 1 (AOI 1)-featuring a vertical logo and a realistic image style-had the highest average viewing duration, with participants fixating on it for an average of 21,786 milliseconds, or 21.786 seconds. In contrast, Style 4 (AOI 4)-which displayed a horizontal logo and a realistic image style-had the shortest average viewing duration, at 6,378 milliseconds, or 6.378 seconds.

Table 2: Summary of comparative analysis of consumer interest data on vitamin water packaging

SUMMARY							
Area of interest (AOI)	**Count**	**Number of Fixations**			**Duration of Fixations (ms)**		
		Sum	**Average**	**Variance**	**Sum**	**Average**	**Variance**
AOI 1	30	653	21.77	102.46	653582	21786	92210655
AOI 2	30	449	14.97	58.86	387428	12914	55467642
AOI 3	30	457	15.23	62.94	317287	10576	37826791
AOI 4	30	283	9.43	16.94	191339	6378	3867806
AOI 5	30	297	9.90	12.30	206660	6889	7264903
AOI 6	30	462	15.40	33.56	442658	14755	23886409

From Table 2, it was found that the variance values, which represent the distribution of data within each Area of Interest (AOI), were clearly different across the six styles. Style 1 (AOI 1) had the highest variance values, reflecting the wide range of interest levels among participants. In contrast, Style 5 (AOI 5) had the lowest variance values, indicating similar levels of interest among participants for that particular packaging style.

Table 3: ANOVA results for fixation count and duration across graphic styles (AOI1-6)

Source of variation		ss	df	MS	F	p-value
Number of fixations (times)	Between groups	3035.58	5	607.11	12.688	$p < .001$
	Within groups	8324.96	174	47.84		
	Total	11360.55				
Duration of fixations (ms.)	Between groups	4910207247	5	982041449	26.71	$p < .001$
	Within groups	6395201973	174	36754034		
	Total	11305409220	179			

From Table 3, the results of the analysis of variance (ANOVA) show that the mean number of fixations and the duration of fixation for the graphics on the six styles of vitamin water packaging are significantly different at the $P < 0.0001$ level. With a p-value less than 0.05, it can be concluded that the mean number of fixations and the duration of fixation for the graphics on the six styles of vitamin water packaging are significantly different, with at least one style differing from the others when considering both the number of fixations and the duration of fixation.

Table 4: Tukey HSD Post-Hoc Pairwise Comparisons of Mean Number of Fixations Across graphic styles (AOI1-6)

Comparison	Mean Difference	SE of Difference	95% Confidence Interval		Adjusted P-Value
			Lower	Upper	
AOI 1- AOI 2	6.80	1.26	1.65	11.95	.003
AOI 1- AOI 3	6.53	1.26	1.39	11.68	.004
AOI 1- AOI 4	12.33	1.26	7.19	17.48	$p < .001$
AOI 1- AOI 5	11.87	1.26	6.72	17.01	$p < .001$
AOI 1- AOI 6	6.37	1.26	1.22	11.51	.006
AOI 2- AOI 3	0.27	1.26	-4.88	5.41	.999
AOI 2- AOI 4	5.53	1.26	0.39	10.68	.027
AOI 2- AOI 5	5.07	1.26	-0.08	10.21	.056
AOI 2- AOI 6	0.43	1.26	-4.71	5.58	.999
AOI 3- AOI 4	5.80	1.26	0.65	10.95	.017
AOI 3- AOI 5	5.33	1.26	0.19	10.48	.037
AOI 3- AOI 6	0.17	1.26	-4.98	5.31	.999

Table 4: (continued) Tukey HSD Post-Hoc Pairwise Comparisons of Mean Number of Fixations Across graphic styles (AOI1-6)

Comparison	Mean Difference	SE of Difference	95% Confidence Interval		Adjusted P-Value
			Lower	Upper	
AOI 4- AOI 5	0.47	1.26	-4.68	5.61	.999
AOI 4- AOI 6	5.97	1.26	0.82	11.11	.013
AOI 5- AOI 6	5.50	1.26	0.35	10.65	.029

The statistical analysis presented in Table 4 (Tukey HSD Post-Hoc Pairwise Comparisons of Mean Number of Fixations) and the design attributes of AOI1–6 detailed in Table 1 (logo and image styles) yield significant insights for packaging design strategy in the vitamin water market. The findings indicated that AOI1, including a vertical logo and realistic image, markedly surpassed all other styles in attracting visual attention (e.g., AOI1 vs. AOI4, AOI5: $p < .001$; AOI1 vs. AOI2, AOI3, AOI6: $p < .01$). On the other hand, the areas with abstract or semi-abstract images and horizontal logos had significantly fewer fixations and were quite similar to each other. The findings indicate that packaging designs for vitamin water that include realistic imagery and vertical logo placement are more effective in capturing and sustaining consumer visual attention.

Table 5: Tukey HSD Post-Hoc Pairwise Comparisons of Mean Duration of Fixations Across graphic styles (AOI1-6)

Comparison	Mean Difference	SE of Difference	95% Confidence Interval		Adjusted P-Value
			Lower	Upper	
AOI 1- AOI 2	8871.80	1106.86	4360.91	13382.69	$p < .001$
AOI 1- AOI 3	11209.83	1106.86	6698.94	15720.72	$p < .001$
AOI 1- AOI 4	15408.10	1106.86	10897.21	19918.99	$p < .001$
AOI 1- AOI 5	14897.40	1106.86	10386.51	19408.29	$p < .001$
AOI 1- AOI 6	7030.80	1106.86	2519.91	11541.69	$p < .001$
AOI 2- AOI 3	2338.03	1106.86	-2172.86	6848.92	.669
AOI 2- AOI 4	6536.30	1106.86	2025.41	11047.19	$p < .001$
AOI 2- AOI 5	6025.60	1106.86	1514.71	10536.49	.002
AOI 2- AOI 6	1841.00	1106.86	-2669.89	6351.89	.848
AOI 3- AOI 4	4198.27	1106.86	-312.62	8709.16	.084
AOI 3- AOI 5	3687.57	1106.86	-823.32	8198.46	.178

Table 5: (continued) Tukey HSD Post-Hoc Pairwise Comparisons of Mean Duration of Fixations Across graphic styles (AOI1-6)

Comparison	Mean Difference	SE of Difference	95% Confidence Interval		Adjusted P-Value
			Lower	Upper	
AOI 3- AOI 6	4179.03	1106.86	-331.86	8689.92	.087
AOI 4- AOI 5	510.70	1106.86	-4000.19	5021.59	.999
AOI 4- AOI 6	8377.30	1106.86	3866.41	12888.19	$p < .001$
AOI 5- AOI 6	7866.60	1106.86	3355.71	12377.49	$p < .001$

The statistical analysis presented in Table 5 (Tukey HSD Post-Hoc Pairwise Comparisons of Mean Duration of Fixations) and the design attributes of AOI1–6 detailed in Table 1 (logo and image styles) indicated that AOI1, including a vertical logo and realistic image, attained the highest average fixation duration, exhibiting statistically significant differences relative to all other AOIs (p <.001). This signifies a robust ability to attract and maintain consumer visual focus. Conversely, AOI4 and AOI5, which employed horizontal logos, exhibited markedly reduced fixation lengths relative to AOI1 (p < .001), indicating diminished visual engagement. Other areas of interest-specifically AOI2, AOI3, and AOI6, which included a semi-abstract and abstract image-showed shorter viewing times compared to AOI1; however, some differences between them were not statistically significant (for example, AOI2–AOI6: p = .848; AOI3–AOI5: p = .178).

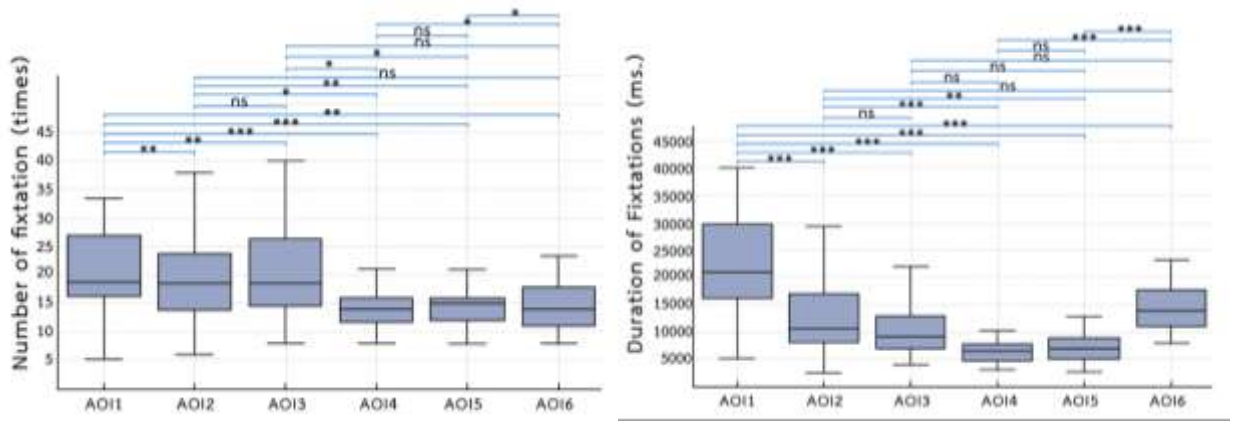

Figure 7: Box plots of pairwise comparisons of fixation counts (left) and fixation durations (right) across vitamin water packaging styles.

From Figure 7 (left), The box plot depicting paired comparisons of number of fixations offers detailed insights that surpass the numerical data in the summary table. Significantly, AOI3, despite having a comparable mean number of fixations to AOI1, demonstrates a far broader range, suggesting variability in its capacity to attract attention. Conversely, AOI4 and AOI5 exhibit both a reduced mean number of fixations and a narrow interquartile range, indicating continuously inadequate visual engagement.

From Figure 7 (Right), The box plot illustrating pairwise comparisons of durations of fixations provides a visual summary of how distinct vitamin water packaging styles influence sustained consumer attention. Beyond confirming AOI1 's superior performance, the plot reveals that AOI6 , although statistically different from AOI1 ($p < .001$), demonstrated relatively longer fixation durations than AOI4 and AOI5 , which had the shortest and most consistent viewing times. Interestingly, despite AOI3 and AOI6 showing similar median durations, their variability differed, suggesting that design complexity may lead to fluctuating engagement.

Figure 8: Example of participant's interest data utilizing a heat map

Figure 8 shows the results of a comparison of participants' visual attention to the graphic styles of vitamin water packaging in the form of a heat map. In the heat map, red areas represent regions where participants fixated for a longer duration, while green areas indicate shorter fixation times. The images show that the center of the screen consistently appears red, indicating longer fixations on the center than on the left and right sides. However, the heat intensity can also shift to the left and right positions in cases where a particular graphic style captures the consumer's interest, regardless of its position on the screen. This suggests that although the center position generally receives the most attention, consumers will still focus on a design they find appealing-even if it is not in the center. For example, Style 1 (AOI 1), which had the longest average viewing time, received consistent attention when shown in all three positions-left, center, and right. When comparing all images, those placed in the center had the highest red intensity, indicating that the center position receives the most visual attention. The left position also showed a high red intensity, though less than the center, showing that the left position can still attract substantial attention. In contrast, the right position consistently had the lowest red intensity and distribution across all images, showing that it receives the least visual attention compared to the other positions.

The results of the data analysis on the graphic styles of vitamin water packaging that influenced consumers' purchasing decisions, using frequency distribution analysis, are shown in Table 6.

Table 6: Results of the frequency distribution analysis showing the graphic styles of vitamin water packaging that influenced participants' purchasing decisions

Consumer choice					
		Frequency	**Percent**	**Valid percent**	**Cumulative percent**
Valid	AOI 1	17	56.67	56.67	56.67
	AOI 2	7	23.33	23.33	80.00
Valid	AOI 3	1	3.33	3.33	83.33
	AOI 4	2	6.677	6.67	90.00
	AOI 5	2	6.67	6.67	96.67
	AOI 6	1	3.33	3.33	100
	Total	30	100	100	

From Table 6, it was found that the majority of participants chose Style 1 (AOI 1), which is a style with graphic elements on the vitamin water packaging in the form of a vertical logo and a realistic image style. This style was selected by 17 participants, accounting for 56.67 percent. From interviews regarding the reasons for choosing this format, it was found that Style 1 evokes a sense of nature, making it most suitable for a product like vitamin water that emphasizes natural origins. Additionally, the logo stands out prominently and exudes beauty.

The analysis of the consistency between the time spent looking at graphic styles on vitamin water packaging and consumers' purchasing decisions was conducted to answer the question: "Does the graphic style on vitamin water packaging that consumers look at the longest have an effect on their purchasing decisions?" The results of this analysis were used to determine the dummy variables for the one-proportion Z-test, as shown in Table 7.

Table 7: Proportion of vitamin water packaging styles that each consumer looked at the longest and the effect on their purchasing decisions

Participant	**Maximum duration of fixation (milliseconds)**	**Graphic style on vitamin water packaging with longest fixation**	**Graphic style chosen by consumer (from questionnaire)**	**Dummy variable**
1	26954	AOI 1	AOI 1	1
2	27454	AOI 1	AOI 1	1
3	19575	AOI 1	AOI 1	1
4	13685	AOI 1	AOI 1	1
5	18674	AOI 2	AOI 2	1

Table 7: Proportion of vitamin water packaging styles that each consumer looked at the longest and the effect on their purchasing decisions

Participant	Maximum duration of fixation (milliseconds)	Graphic style on vitamin water packaging with longest fixation	Graphic style chosen by consumer (from questionnaire)	Dummy variable
6	16009	AOI 1	AOI 1	1
7	20821	AOI 1	AOI 1	1
8	30967	AOI 2	AOI 2	1
9	19156	AOI 2	AOI 2	1
10	22081	AOI 4	AOI 6	0
11	30397	AOI 1	AOI 1	1
12	30333	AOI 1	AOI 1	1
13	29938	AOI 2	AOI 2	1
14	25792	AOI 5	AOI 5	1
15	21427	AOI 5	AOI 5	1
16	20206	AOI 2	AOI 2	1
17	33613	AOI 1	AOI 1	1
18	28030	AOI 5	AOI 4	0
19	34009	AOI 3	AOI 3	1
20	27988	AOI 2	AOI 2	1
21	24944	AOI 1	AOI 1	1
22	25489	AOI 1	AOI 1	1
23	30653	AOI 1	AOI 1	1
24	21161	AOI 1	AOI 1	1
25	40212	AOI 1	AOI 1	1
26	36396	AOI 1	AOI 1	1
27	16390	AOI 2	AOI 2	1
28	18122	AOI 6	AOI 4	0
29	36670	AOI 1	AOI 1	1
30	18837	AOI1	AOI 1	1

Table 8: Results of the one-proportion Z-test: consistency between longest viewing duration and purchasing decisions for vitamin water packaging styles

One proportion Z-test	
Number of participants whose purchasing decision was consistent with the longest viewing duration	27
Number of participants whose purchasing decision was inconsistent with the longest viewing duration	3
Total sample size (n)	30
Observed proportion	90%
Expected proportion	50%
Z-statistic	4.3818
p-value	$p < .001$

The analysis results indicate that the proportion of participants whose chosen graphic style of vitamin water packaging-namely, the one that had the most influence on their purchasing decision-was consistent with the style that the participant looked at the longest, and the proportion of participants whose chosen graphic style of vitamin water packaging was inconsistent with the style that the participant looked at the longest were significantly different. This conclusion is supported by a p-value < 0.001, which is less than the significance level of 0.05. Therefore, the null hypothesis (H_1: $p \geq 50\%$) was not rejected. It can be concluded that the graphic style of the vitamin water packaging that each consumer looked at the longest had a significant effect on their decision to buy the product, as shown in Table 8.

V. CONCLUSION AND DISCUSSION

The research findings revealed that the graphic style of vitamin water packaging with a vertical logo and realistic image style (AOI 1) was rewritten it to vertical logo and realistic image style (AOI 1) as shown in Figure 9. It received the most attention from consumers, both in terms of the number of fixations and the duration of fixations. There was a clear consistency between the packaging style that received the most attention and the style that significantly influenced purchase decisions. These behavioral insights can serve as practical guidelines for designing clearer and more prominent graphic styles of vitamin water packaging. Specifically, using a vertical logo, realistic imagery with natural shadows, and placing the product in the center of the shelf, which is the area that receives the most attention, can increase the chance of consumers seeing the product and making a decision to purchase it. In addition, while the center position proves most effective, the left and right areas of the shelf should not be overlooked, as they also have the potential to attract attention to a certain extent.

The research results are consistent with the findings of Kang et al. (2014, pp. 113-120), who stated that vertical logos influence consumer preferences. They are also consistent with those of Febriant et al. (2023, pp. 5-12), who found that realistic images attracted more attention than computer-generated illustrations, especially when used with display typography. Similarly, Kattibut (2022, p. 87) confirmed that a clear logo can effectively enhance brand credibility and recognition. This finding is also consistent with those of Oliveira (2016, pp. 160-167) and Bialkova et al. (2020, pp. 1-44), who used eye-tracking technology with other products and found that the duration of fixation was directly related to consumer interest in the product and purchasing behavior. Consumers often using gaze patterns to assess product value, essence, and emotional connection. Therefore, the selection of images that convey freshness, naturalness, and product value is an important guideline for designing packaging that can truly meet consumer needs and support entrepreneurs in developing effective and sustainable products and marketing strategies.

Figure 9: Example of vitamin water packaging applying vertical logo and realistic image based on research findings

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INTERNATIONAL JOURNAL of Industrial Education and Technology

THE EFFECT OF SSCS LEARNING MANAGEMENT COMBINED WITH BRAINSTROMING TECHNIQUE ON PROBLEM-SOLVING ABILITY AND MATHEMATICAL LEARNING ACHIEVEMENT OF GRADE 6 STUDENTS

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Received: June 4, 2025 **Revised:** June 16, 2024 **Accepted:** June 28, 2025

Citation reference :
Ruanthai, W., Insombat, B., & Hombubpha, S. (2025). The effect of SSCS learning management combined with brainstroming technique on problem-solving ability and mathematical learning achievement of Grade 6 students. **International Journal of Industrial Education and Technology, 7** (1), 46-58.

ABSTRACT

This research was to compare the mathematical problem-solving ability and learning achievement in mathematics of Grade 6 students pre-post receiving learning using SSCS learning management combined with brainstorming techniques, and to compare students' post-learning problem-solving ability and learning achievement against the 70 percent criterion of the full score. The sample group in this study consisted of 12 students of Grade 6 from Wat Nong Kradon School, also under the Office of the Nakhon Sawan Primary Educational Service Area 1, totaling 1 classroom, selected using cluster random sampling. The research instruments included to six lesson plans on the topic of decimals based on SSCS learning management with brainstorming techniques on the topic of statistic with quality level 4.59, a 10-item mathematical problem-solving ability test with 0.48 - 0.63 difficulty index, 0.43 - 0.69 discrimination index and 0.71 reliability, and a 30-question mathematics learning achievement test with 0.25 - 0.75 difficulty index, 0.20 - 0.93 discrimination index and 0.72 reliability. The data were analyzed using mean, standard deviation, dependent-sample t-tests, andone-sample t-tests. The findings revealed that Grade 6 students' mathematical problem-solving ability and learning achievement after learning were significantly higher than before learning at the .05 level of statistical significance. Furthermore, the students' post-learning scores were significantly higher than the 70 percent criterion of the full score at the .05 significance level.

Keywords: SSCS learning management, Brainstorming technique, Mathematical problem-solving ability, Learning achievement

I. INTRODUCTION

Mathematics is a science with unique characteristics, distinct from other fields of study. Humans use mathematics both intentionally and unintentionally. However, mathematics deals with abstract concepts that are intangible. Few people clearly perceive the characteristics of mathematics. Mathematics is characterized by a clear structure, system, and pattern directly related to thinking, wisdom, the use of symbols to convey meaning, calculate, reason, and solve problems. It is a guide of learning through the integration of prior knowledge with new knowledge independently (Khammanee, 2021, pp. 90-96). Mathematics is a tool for finding accurate answers in various situations and for predicting future events (Makanong, 2010, pp. 1-2). Mathematical problem-solving ability refers to the capacity of finding methods for obtaining solutions to mathematical problems. This requires knowledge, reasoning, and the application of existing knowledge to solve new problems using various approaches. It involves applying mathematical knowledge in real life situations and consists of the following to understanding the problem planning the solution, following the plan, and summarizing the result (Angganapattarakajorn, 2023, pp. 54-66; Institute for the Promotion of Teaching Science and Technology [IPST], 2012, p. 127; Makanong, 2010, p. 174; Polya, 1980, pp. 5-40). Currently, student assessments are aligned with their mathematics problem-solving abilities. This can be seen from the result of the Ordinary National Educational Testing Service or O-NET scores (National Institute of Educational Testing Service [NIETS], 2023, Online; 2024, Online; 2025, Online) from the academic year 2021 to 2023 found that Grade 6 students had average test scores in mathematics of 29.99, 36.83, and 29.96 points, respectively, in accordance with the O-NET test results of Wat Nong Kradon School, it was found that the average score of the Mathematics at the Grade 6 level was 32.90, 19.24, and 19.05 points, respectively, which are all below 50 percent. These results indicate that exploring learning methods that influence students' mathematical problem-solving abilities and academic achievement remains both significant and necessary. Learning based on the theory of Constructivism emphasizes the notion that learning involves constructing cognitive structures, enabling students to resolve problematic situations and apply tools to solve problems and other related situations. Students must create knowledge in a variety of ways. Based on existing knowledge as a component, and on the teacher's side, they are responsible for expanding existing knowledge and adding new knowledge (Khammanee, 2021, pp. 290-291). The teacher's teaching methods are essential in organizing teaching and learning activities because teaching methods will help increase learning efficiency, make lessons more interesting, and motivate students to be more interested in learning (Khammanee, 2021, pp. 324-325). In addition to the theory of self-knowledge creation, another learning theory that can be used in managing mathematics learning is Sternberg's information processing learning theory (Sternberg, 1986, pp. 41-78), which has steps in the thinking process leading to problem-solving, namely, the step of defining the nature of the problem, reviewing the problem to understanding, setting goals and defining the problem to lead to the set goals, selecting components or steps necessary to solve the problem, and determining the steps so that each is of suitable complexity. The first step should be simple as a good starting point before proceeding to the next steps. Each step should be carefully considered in detail. The step of selecting strategies to organize the elements in solving the problem must ensure thorough consideration of the problem and avoid confusing conclusions. The sequence of steps should follow the nature of the problem or logical reasoning that leads to the desired goal, as errors may occur. The step of selecting mental representations for problem-related information requires understanding one’s own abilities and using various forms of internal and external mental representations. The step of identifying useful sources of information requires devoting time and fully applying existing knowledge to carefully plan which information sources to use. Flexibility is needed to adjust plans and information sources in accordance with the problem-solving context and to constantly seek new

and useful information sources. The step of evaluating the problem-solving method determines whether the chosen approach effectively leads to the established goal. From the learning theory mentioned above, the researchers have studied the concepts, theories, and principles of organizing effective teaching and learning activities and promoting students' problem-solving abilities even more. From studying research related to mathematics learning management, the researchers have chosen a learning management model to study: Search, Solve, Create, and Share (SSCS) learning management combined with brainstorming techniques.

SSCS learning management combined with brainstorming technique is a learning approach the researchers synthesized by integrating SSCS learning management and the brainstorming technique. SSCS learning management was developed by Pizzini et al. (1989, pp. 523-532) based on scientific problem solving. It is used to manage learning that focuses on students, to practice problem-solving skills, and to use logical thinking processes by themselves. The teacher is the only one who defines the problem, encourages students to study and research, face the problem, analyse, plan, implement problem-solving, and exchange knowledge to find the solution. The goal is to enable students to develop knowledge, understanding, and problem-solving skills, to confront problems and solve them step by step by applying their understanding and the problem-solving process. This will enhance students' problem-solving ability (Sutthirat, 2009, pp. 411- 419), which is consistent with the research of Juntuma et al. (2022, pp. 176-189), who found that Grade 5 students who learned using the open-ended approach with the SSCS model had a significantly higher problem-solving ability and mathematics achievement after learning than beforelearning at a statistically significant level of .05, and the research results of Silaporn and Khamrat (2020, pp. 89-102) found that secondary 4 students had a significantly higher problem-solving ability and mathematics achievement after learning than before learning at a statistically significant level of .05.

Another technique that can develop mathematical problem solving simultaneously is the brainstorming technique. It is a group exchange activity developed by Osborn (1957, p. 228) based on the creativity theory of E. Paul Torrance. According to Torrance’s creative thinking process, it begins with identifying facts and discovering the problem. Once the root of the problem is identified, hypotheses are formulated. Then, relevant information is gathered, and the hypothesis is tested until a solution is found. After that, the result is verified. Guilford's theory of creativity explains three dimensions of human intelligence: content dimension, operational dimension, and product dimension (Thongleud, 2020, pp. 74-78). Brainstorming emphasizes the quantity of ideas by letting the ideas flow freely. There will be no judgment or criticism until it is complete. Then, those ideas are evaluated, improved, refined, and combined to get the best idea, which is a learning management approach to enable students to have the ability to solve problems. The brainstorming process involves presenting a situation and encouraging members to express as many opinions as possible without criticism. Participants share their ideas systematically to arrive at the best solution, leading to effective problem-solving. From the study of research on the use of brainstorming techniques, it is a technique that can develop the ability to solve mathematical problems to a higher level (Bungkilo & Heingraj, 2014, pp. 140-148; Daungkhamjan & Pavaputanon, 2015, pp. 63-70; Jainan & Art-In, 2019, pp. 23-33; Powiangkham & Heingraj, 2014, pp. 77-84).

The objective of this research is to compare the mathematical problem-solving ability and learning achievement in mathematics of Grade 6 students pre-post receiving learning and the 70 percent criterion of the full score learning using SSCS learning management model combined with brainstorming techniques.

II. LITERATURE REVIEW

The researchers studied the research results related to SSCS learning management combined with brainstorming techniques of Jainan and Art-in (2019, pp. 23-33). The research results found that Grade 11 students had problem-solving skills and academic achievements in mathematics after receiving the learning management higher than the specified criteria of 70 percent, and the number of students who passed was higher than the specified criteria of 70 percent, which was statistically significant at the .05 level. Similarly, the research of Silaporn and Khamrat (2020, pp. 89-102). The research results found that Grade 10 students could solve problems and achieve academic performance in mathematics after receiving the learning management that was higher than the 70 percent criterion, with a statistical significance of .05, and their academic achievement in mathematics after receiving the learning management was significantly higher than before receiving the learning management, at a statistical significance level of .05. This is also consistent with the research of Syafri et al. (2020, pp. 309-317). The research results found that the mathematics problem-solving ability of students who received SSCS learning management was higher than that of students who received the regular learning management, with statistical significance at the .05 level. In addition, the researchers studied the research results specifically in the scope of learning management using the brainstorming technique of Saeho (2021, pp. 35-37). The research results found that academic achievement in mathematics after receiving the learning management was higher than before receiving the learning management. The control group's academic achievement was significantly higher than that of the experimental group, at a statistical significance level of .05. In addition, the research of Namnual and Chanprasert (2022, pp. 330-345). The research results found that Grade 12 students were most satisfied. The average score after receiving the learning management was higher than before receiving the learning management, significantly at the .05 level, which is consistent with the researchers studied the research results specifically for the scope of SSCS learning management by Phankanok and Intasena (2022, pp. 223-238). The research results found that Grade 11 students had overall satisfaction at a high level. The ability to solve mathematics problems after receiving the learning management was higher than before receiving the learning management significantly at the .05 level. Similarly, the research of Hadaming (2021, pp. 334-337). The research results found that the average score before receiving the learning management was 65.55, and the average score after receiving the learning management was 89.78. It can be concluded that students with higher self-efficacy tend to demonstrate greater problem-solving ability in mathematics, with statistical significance at the .05 level. This is consistent with the research of Metta et al. (2021, pp. 124-137). The research found that Grade 5 students could solve problems and be creative after receiving the learning management higher than 70 percent criterion, which was statistically significant at the .05 level. Similarly, Nancharee et al. (2021, pp. 125-139). The research results found that Grade 9 students had academic achievement in mathematics after receiving the learning management higher than the 70 percent criterion and could solve mathematics problems higher than the 70 percent criterion, which was statistically significant at the .05 level. Similarly, the research of Awiria and Septiani (2018, pp. 108-113). The research results concluded that Grade 5 students who received learning through brainstorming techniques showed significantly higher academic achievement in mathematics on fractions, with a statistical significance level of .05. Similarly, the research of Anaguna and Suhendra (2018, pp. 1-6). The research results concluded that Grade 8 students who learned through the Knisley learning model combined with brainstorming techniques showed a statistically significant increase in academic achievement in mathematics at the .05 level. This is also consistent with the research of Quaba (2021, pp. 1050-1075). The study results found that students who received learning using the brainstorming technique scored significantly higher than those in the control group, at a statistically significant level of .05.

The research hypothesis is that Grade 6 students have higher problem-solving ability and academic achievement in mathematics after receiving learning management using the SSCS model combined with the brainstorming technique than before receiving it. Furthermore, their problem-solving ability and academic achievement in mathematics after receiving the SSCS model combined with brainstorming technique are higher than the 70 percent criterion of the full score.

III. RESEARCH METHODOLOGY

This research is a pre-experimental design with a single-group sample research plan with a pre-and post-test (Koonkaew, 2023b, p. 13). The sample group in this study consisted of 12 students of Grade 6 from Wat Nong Kradon School, also under the Office of the Nakhon Sawan Primary Educational Service Area 1, totaling 1 classroom, selected using cluster random sampling. The independent variable used in this research was SSCS learning management combined with the brainstorming technique. The dependent variables were mathematical problem-solving ability and mathematical learning achievement as shown to Figure 1.

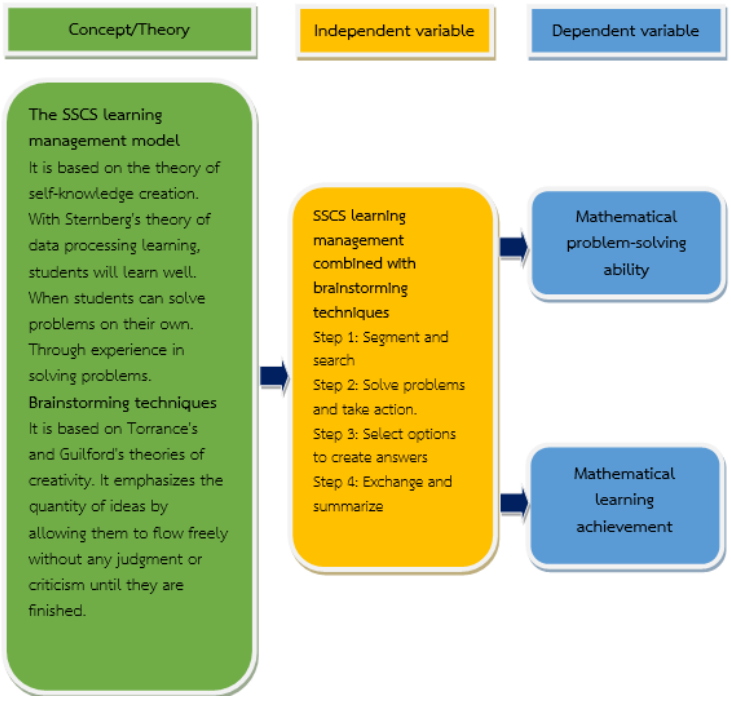

Figure 1: Research methodology

The experiment was conducted, and data was collected as follows to pretest consisting of a mathematics problem-solving ability test, and a mathematical learning achievement test. The scores were recorded as pretest scores for use in data analysis. The teaching experiment was conducted using SSCS learning management combined with brainstorming techniques plan for a total of 15 learning hours during the second semester of the 2024 academic year. The learning process was carried out according the following steps to search and segment, solve problem and take action, select options to create answers, and exchange and summarize. The learning process was carried out according to the following independent variable by Figure 1. After the experiment, the Grade 6 students in the sample group took a posttest using the same mathematics problem-solving ability test and mathematics achievement test on decimals as in the pretest. The duration for each test remained the same. The scores were recorded as posttest

scores, and pretest and posttest scores from both the problem-solving ability test and the mathematical achievement test were analyzed data by mean and standard deviation, testing for normal distribution assumptions, and conducting a one-sample t-test as well as a paired-sample t-test to summarize the results.

IV. RESULTS

Table 1: The results of the quality assessment of SSCS learning management model combined with brainstorming techniques lesson plans by three experts

Lesson plan	$\bar{x}$	SD	Quality
Writing fractions in decimal form	4.53	0.32	Highest
Dividing decimals by decimals	4.57	0.33	Highest
Dividing a number by a decimal	4.62	0.24	Highest
Currency exchange problems	4.66	0.25	Highest
Measurement Problems	4.63	0.24	Highest
Problems related to decimals	4.54	0.32	Highest
Total score		**4.59**	**Highest**

From Table 1, SSCS learning management combined with the brainstorming technique lesson plans, a total of 6 lesson plans covering 15 learning hours was used in this study. Assessed by the plan alignment assessment with learning objectives on a 5-level scale. The plans received the highest average suitability rating to highest (Koonkaew, 2023a, p. 121; Koonkaew, 2023b, p. 136; Sutthirat et al., 2023, p. 139).

Table 2: The results of the difficulty and discrimination index of the mathematical problem-solving ability test by 20 non- sample students

Items	S_U	S_L	n	X_{max}	X_{min}	P	D
1	37	30	5	8	5	0.57	0.47
2	37	29	5	8	5	0.53	0.53
3	37	28	5	8	4	0.63	0.45
4	36	29	5	8	5	0.50	0.47
5	29	12	5	8	0	0.51	0.43
6	38	33	5	8	6	0.55	0.50
7	34	25	5	8	4	0.48	0.45
8	37	13	5	8	1	0.57	0.69
9	36	29	5	8	5	0.50	0.47
10	26	9	5	7	0	0.50	0.49
			α				0.71

when	S_U	mean	Sum of high group scores.
	S_L	mean	Sum of low group scores.
	X_{max}	mean	Highest score.
	X_{min}	mean	Lowest score.
	P	mean	Whitney and Sabers's difficulty index.
	D	mean	Whitney and Sabers's Discrimination index.
	α	mean	Cronbach's alpha reliability coefficient.

From Table 2, a subjective mathematics problem-solving ability test consisting of 10 items that required students to show their solution processes. The test values ranging from Whitney and Sabers difficulty index (P) ranging from 0.48 to 0.63, a discrimination index (D) ranging from 0.43 to 0.69 (Koonkaew, 2023a, p. 239), and a Cronbach's alpha reliability coefficient (α) of 0.71 (Koonkaew, 2023a, p. 241).

Table 3: The results of the difficulty and discrimination index of the mathematical learning achievement test by 20 non-sample students

Items	*U*	*L*	n_1	n_2	*p*	*B*
1	5	5	5	15	0.50	0.67
2	3	6	5	15	0.45	0.20
3	5	10	5	15	0.75	0.33
4	5	7	5	15	0.60	0.53
5	3	2	5	15	0.25	0.47
6	5	7	5	15	0.60	0.53
7	3	5	5	15	0.40	0.27
8	4	9	5	15	0.65	0.20
9	4	3	5	15	0.35	0.60
10	4	9	5	15	0.65	0.20
11	4	7	5	15	0.55	0.33
12	5	7	5	15	0.60	0.53
13	5	9	5	15	0.70	0.40
14	5	5	5	15	0.50	0.67
15	3	5	5	15	0.40	0.27
16	5	3	5	15	0.40	0.80
17	3	3	5	15	0.30	0.40
18	4	6	5	15	0.50	0.40
19	4	5	5	15	0.45	0.47
20	2	3	5	15	0.25	0.20
21	5	5	5	15	0.50	0.67
22	3	4	5	15	0.35	0.33
23	3	6	5	15	0.45	0.20
24	4	6	5	15	0.50	0.40
25	3	4	5	15	0.35	0.33
26	3	3	5	15	0.30	0.40
27	5	1	5	15	0.30	0.93

Table 3: (continued) The results of the difficulty and discrimination index of the mathematical learning achievement test by 20 non-sample students

Items	*U*	*L*	n_1	n_2	*p*	*B*
28	5	3	5	15	0.40	0.80
29	5	4	5	15	0.45	0.73
30	5	5	5	15	0.50	0.67
			r_α			0.72

when	***U***	mean	The number of candidates who answered correctly in the qualifying group.
	L	mean	The number of candidates who answered correctly of the group did not meet the criteria.
	n_1	mean	Number of qualified candidates.
	n_2	mean	Number of candidates who did not pass the exam.
	p	mean	Difficulty index.
	B	mean	Brennan's discrimination index.
	r_α	mean	Lovett's reliability coefficient.

From Table 3, a 30-item multiple-choice mathematical learning achievement test was also used. The test values a difficulty index (p) ranging from 0.48 to 0.63 (Koonkaew, 2023a, p. 225), a criterion-referenced discrimination index (B) according to Brennan ranging from 0.43 to 0.69 (Koonkaew, 2023a, p. 233), and a reliability coefficient (r_α) according to Lovett of 0.72 (Koonkaew, 2023a, p. 235).

Table 4: The comparative results of the mathematical problem-solving ability of grade 6 students before and after learning, and criterion of 70 percent of the full score receiving SSCS learning management combined with brainstorming techniques by 12 sample students

Testing	n	Full score	70 percent criteria	$\bar{x}$	SD	df	t	Sig.
Pre-test	12	80	56	29.08	11.22	11	9.211	0.000*
Post-test	12	80		60.83	6.20			

*Statistically significant at the .05 level.

From Table 4, it was found that Grade 6 students who received SSCS learning management combined with the brainstorming technique had a mean pretest score for mathematical problem-solving ability of 29.08 with a standard deviation of 11.22, and a mean posttest score of 60.83 with a standard deviation of 6.20. The mathematical problem-solving ability after learning was significantly higher than before learning, and higher than the 70 percent criterion of the full score at the .05 level of statistical significance.

Table 5: The comparative results of the mathematical learning achievement of Grade 6 students before and after learning, and criterion of 70 percent of the full score receiving SSCS learning management combined with brainstorming techniques by 12 sample students

Testing	n	Full score	$\bar{x}$	70 percent criteria	SD	df	t	Sig.
Pre-test	12	30	11.91	21	4.69	11	6.133	0.000*
Post-test	12	30	22.25		2.30			

*Statistically significant at the .05 level.

From Table 5, it was found that Grade 6 students who received SSCS learning management combined with the brainstorming technique had a mean pretest score for mathematics learning achievement of 11.91, with a standard deviation of 4.69, and a mean posttest score of 22.25, with a standard deviation of 2.30. The mathematical learning achievement after learning was significantly higher than before learning, and higher than the 70 percent criterion of the full score at the .05 level of statistical significance.

V. CONCLUSION AND DISCUSSION

The research findings were as follows to Grade 6 students who received using SSCS learning management combined with brainstorming techniques had a pre-learning average mathematical problem-solving ability score of 29.08 with a standard deviation of 11.22, and a post-learning average score of 60.83 with a standard deviation of 6.20, and Grade 6 students who received using SSCS learning management combined with brainstorming techniques had a pre-learning average academic achievement score of 11.91 with a standard deviation of 4.69, and a post-learning average score of 22.25 with a standard deviation of 2.30. The findings revealed that Grade 6 students' mathematical problem-solving ability and learning achievement after learning were significantly higher than before learning at the .05 level of statistical significance. Furthermore, the students' post-learning scores were significantly higher than the 70 percent criterion of the full score at the .05 significance level.

The posttest mathematical problem-solving ability and learning achievement score was significantly higher than the pretest score, and higher than the 70 percent criterion of the full score at the .05 level of statistical significance. This finding indicates that SSCS learning model combined with brainstorming effectively enhances students' problem-solving abilities. It promotes interactive learning and collaborative analytical thinking, which clearly improves students' problem-solving performance. This result is consistent with Khammanee (2021, pp. 290 - 291), who stated that students construct knowledge through multiple approaches by building on prior knowledge, while teachers play a role in expanding existing knowledge and introducing new concepts. It also aligns with the findings of Jainan and Art-In (2019, pp. 23 - 33), who found that students' mathematical problem-solving ability significantly increased after participating in learning activities based on the SSCS model and brainstorming techniques, with posttest scores also exceeding the 70 percent criterion. Moreover, the results correspond with the study by Butwan and Prasertsang (2021, pp. 43 - 51), which found that Grade 6 students who received SSCS learning management demonstrated very high levels of mathematical problem-solving skills, and their posttest scores were significantly higher than their pretest scores at the .05 significance level.

SUGGESTION

In implementing SSCS learning management combined with brainstorming techniques, teachers are encouraged to explore its effectiveness in other mathematics learning units to examine students' problem-solving abilities and academic achievement across different content areas. Teachers should also prepare thoroughly in advance by studying lesson details and clearly outlining learning activities to ensure smooth and effective classroom learning. Moreover, when applying the SSCS model with brainstorming, teachers should pose thought-provoking questions that continuously stimulate student thinking throughout each session. They should incorporate problems or situations that reflect local contexts or everyday life and may also allow students to formulate their own problems. Extending the learning period beyond the timeframe used in this study such as over an entire semester or academic year-could support long-term tracking of learning outcomes. Finally, future research on SSCS learning management with brainstorming techniques should also consider other educational variables beyond problem-solving ability and academic achievement, such as student attitudes, connection-making skills, reasoning ability, and communication and expression skills.

ACKNOWLEDGMENTS

The researchers would like to express sincere gratitude to the Faculty of Education, Nakhon Sawan Rajabhat University, for generously providing funding and institutional support for this research. Special thanks are also extended to the all lecturers, whose academic learning, thoughtful recommendations, and encouragement have greatly contributed to the successful completion of this research. The knowledge and experience gained throughout the study program have enabled the researchers to apply and integrate academic learning into the research, thereby enhancing the quality and completeness of this research.

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INTERNATIONAL JOURNAL of Industrial Education and Technology

THE DEVELOPMENT OF MODERN LEARNING ACTIVITIES AND STRENGTHENING TRAINING MODEL TO PROMOTE DIGITAL SKILLS FOR VOCATIONAL TEACHERS IN THAILAND

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Received: June 5, 2025 **Revised:** June 12, 2025 **Accepted:** June 28, 2025

Citation reference :
Klinbumrung, K., Surpare, K., & Sukmak P. (2025). The development of modern learning activities and strengthening training model to promote digital skills for vocational teachers in THAILAND. **International Journal of Industrial Education and Technology,** 7 (1), 59-71.

ABSTRACT

The research aims to develop modern learning activities and enhance training models to promote digital skills for Vocational teachers in Thailand. A sample group of 50 teachers from two curricula, Industrial Engineering and Business, was selected from the Office of the Vocational Education Commission in Samut Sakhon Province, Thailand, in 2023, selected by the voluntary method. The research instruments in this research was as follows: 1) the modern learning activities and strengthening training model, 2) the training handbook, 3) the achievement test, 4) the evaluation forms of creating digital media, and 5) the trainee satisfaction assessment. The study was conducted using a one-group pretest-posttest experimental design, with the training and data collection carried out over a total duration of approximately 21 hours. The statistical methods used in this research included the mean, percentage, standard deviation, and t-test for dependent samples. The research results found that 1) The evaluation result of the quality of the training model that enhances modern learning activities is at a high level ($\bar{x}$ = 4.45, SD = 0.19), 2) The trainees' digital skill scores significantly increased after the training with a statistically significant difference at the .05 level ($p < .05$), 3) Trainees have high-level skills in creating digital media and modern learning activities ($\bar{x}$ = 4.01), equivalent to 80.24%, and 4) The trainees are high satisfied with modern learning activities and strengthening training model to promote digital skills ($\bar{x}$ = 4.34, SD = 0.17). Therefore, the developed training model can effectively promote trainees' knowledge and skills in digital media.

Keywords: Modern learning activities, Training model, Activity-based learning, Digital skill, Vocational teachers

I. INTRODUCTION

Technology is integral to daily life, but education remains key to human development. Teachers play a vital role in delivering quality learning and equipping students with the knowledge and skills needed for success in both work and life, despite rapid technological change (Ariya et al., 2023, pp. 33-46). The Master Plan under the National Strategy (B.E. 2566–2580) (Office of the National Economic and Social Development Council, 2023, pp. 12-1-12-11) emphasizes access to high-quality, internationally standardized education. It promotes 21st-century skills such as problem-solving, communication, and lifelong learning, support digital learning systems, and encourages the development of Thai individuals based on multiple intelligences to maximize potential and career readiness in line with educational standards.

21st-century learning should be structured from early childhood through higher education, emphasizing interdisciplinary thinking, scientific and mathematical knowledge, logical reasoning, and practical application (Panyaprouks, 2019, pp. 31- 40). According to the national strategy, teachers must shift into modern educators, motivators and designers of innovative learning experiences. To enhance student outcomes, teachers are expected to conduct research and apply pedagogical knowledge in instructional practices. In the digital age, driven by Thailand's 4.0 policy that highlights students as innovators, teachers must integrate computers, telecommunication, and network technologies into their teaching (Boonyasana, 2022, pp. 82-86). Generation Z learners are tech-savvy and fast learners, requiring modern, engaging educational media tailored to their needs (Pimdee & Pipitgool, 2023, pp. 540-549). Thus, teachers must consistently innovate instructional materials and adapt to technological change (Louimsai et al., 2017, pp. 284-295). For vocational teachers in particular, digital skills are no longer optional but essential. They are responsible for preparing students for technologically advanced workplaces where digital systems are deeply embedded in daily operations. Teachers who lack digital proficiency may face difficulties in managing online instruction, utilizing industry-relevant software etc. Findings from the Electronic Monitoring and Evaluation Vocational System (e-MVS) in 2022 revealed that curriculum development for training teachers and staff in vocational institutions remains insufficient, with many areas lacking coverage (Office of the Vocational Education Commission, 2022, pp. 1-23). Consequently, educational institutions must prioritize teacher readiness by providing professional development focused on digital pedagogy (Simonics, 2020, pp. 4-6). Training should be led by knowledgeable, skilled personnel who can guide teachers in implementing technology-aligned instructional strategies (Ouppinjai & Yawirach, 2019, pp. 51-65).

Activity-based learning management is a learning management approach that can encourage learners to understand teaching and learning management practices and develop innovative teaching materials to be modern and aligned with learners in the digital era appropriately. Activity-based learning is an integral part of the "learning by doing" concept proposed by John Dewey, where learners participate in the learning process, engage in hands-on activities and emphasize the acquisition of knowledge and understanding through group activities, fostering teamwork skills, and promoting self-directed learning, which fosters continuous knowledge acquisition (Nwoke, 2021, pp. 70-76).

From this background, the researcher developed a training model that enhances modern learning activities in the 21st century to promote vocational teachers' competency in digital skills and experiment with training vocational teachers to develop information technology competencies for teaching and learning using digital technology, organizing modern learning activities, creating learning resources, establishing virtual classrooms, and modern instructional media management methods that align with current technological advancements, which can develop learners to have the potential to be high-quality digital citizens capable of driving Thailand forward in the future which research objectives include: 1) to develop modern learning activities and strengthen training models to promote digital competency, 2) to compare trainees'

academic achievement before and after instruction using the developed training models, 3) to develop trainees' digital media creation skills using developed training models and 4) to study the satisfaction of trainees with developed training models.

II. LITERATURE REVIEW

The importance of digital skills in education has increased significantly in the context of 21st-century learning. Bunchoo Jaisai (Jaisai et al., 2021, pp. 1-10) proposed that digital integration in educational institutions should be supported by three administrative pillars, learning environments, academic leadership, and digital infrastructure. These elements are vital for establishing effective training systems. Koranat Titakornpongsathit (Titakornpongsathit & Sriputtarin, 2022, pp. 189-206), emphasized the necessity of digital literacy, instructional software proficiency, and pedagogical strategy development for modern educators. Cheryl Brook (Brook & Pedler, 2020, pp. 100415) advocated for action learning as a reflective approach that bridges theoretical concepts with practical application. Panutda Aphichasirikul (Aphichasirikul et al., 2024, pp. 47-65) highlighted application-based competencies, such as using YouTube, Google Sites, and Canva, as essential for enhancing active learning. These perspectives align with the Digital Competence of Educators framework by Christine Redecker (Redecker, 2017, pp. 12-17), which outlines six dimensions of digital competence, ranging from resource creation to learner engagement. Collectively, these studies provide a theoretical foundation for the development of training models that promote modern learning activities and digital skills in vocational education.

This study assumes that vocational teachers require structured training aligned with current pedagogical demands. The conceptual framework draws upon Fan Wang (Wang et al., 2024, pp. 409-431), whose outcome-based model emphasizes learner-centered design, performance-based objectives, and continuous improvement through feedback. Key components need analysis, curriculum alignment, and applied learning. The framework is enhanced by integrating the Digital Competence of Educators competencies (Redecker, 2017, pp. 12-17), and application-based tools presented by Panutda Aphichasirikul (Aphichasirikul et al., 2024, pp. 47-65). Moreover, the five-step activity-based learning process comprising goal setting, task design, hands-on participation, reflection, and assessment proposed by Chanasith Sithsungnoen (Sithsungnoen et al., 2022, pp. 89-110) fosters deep engagement and critical thinking. Lastly, administrative factors identified by Bunchoo Jaisai (Jaisai et al., 2021, pp. 1-10) reinforce the institutional support necessary for sustaining digital teaching practices. Together, these concepts guide the construction of an effective training model for vocational teachers in delivering technology-integrated, learner-centred instruction.

III. RESEARCH METHODOLOGY

The researchers planned the experiment using a quasi-experiment, a one-group pretest and posttest design (Koocharoenpisal et al., 2022, pp. 45-59), to assess the effectiveness of the developed training program in promoting digital skills among vocational teachers. This research design was chosen due to its suitability for applied educational settings, where random assignments are often not feasible. It enables the measurement of changes in participants' performance before and after the intervention within the same group. The researcher conducted the research according to the following steps:

3.1 Participants

The sample group consisted of 50 vocational teachers who taught at the Office of the Vocational Education Commission, Samut Sakhon Province, Thailand, in 2023 from two curricula: Industrial Engineering and Business. The voluntary selection method was applied by distributing a recruitment announcement via internal email to personnel within the college, allowing interested teachers to register for participation.

3.2 Content Scope in Training Course

The training course, which used modern learning activities, was designed on the subject of digital skills for vocational education. The training content is divided into four units: Unit 1, "Teachers in the 21st Century," focuses on essential life skills, the evolving role of educators, and strategies for effective educational management. Unit 2, "Modern Teaching Models," introduces concepts such as learning how to learn and knowledge management to support innovative teaching practices. Unit 3, "Activity-Based Learning," emphasizes student-centered learning, hands-on experience based on the principle of learning by doing, and appropriate methods of assessment. Unit 4, "Development of Digital Media," covers the creation of digital resources, management of virtual classrooms, and the application of modern technology in instructional roles as shown in Figure 1. The entire program is delivered over 21 hours within three days and adopts a practical workshop format. This format encourages participants to actively engage in content development, media creation, and instructional planning.

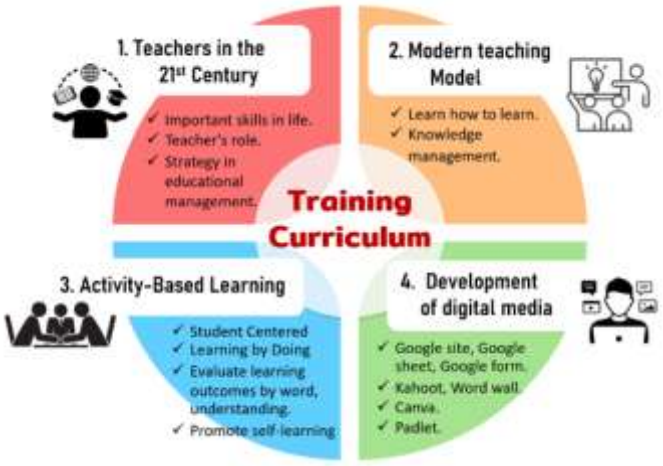

Figure 1: Training curriculum

3.3 Conceptual Framework

The conceptual framework of this study, which focuses on the development of modern learning activities and strengthening the training model to promote digital skills for vocational teachers with the independent variables: Training model integrated with modern learning activities consisted of the following steps: 1) Inspire, 2) Study and Discuss, 3) Practice, 4) Outcome of activity, and 5) Evaluate. The dependent variables are trainees' learning achievement, skill in creating digital instructional media, and trainees' satisfaction. The relationship between the variables is illustrated in Figure 2, which guides the overall research process and assessment.

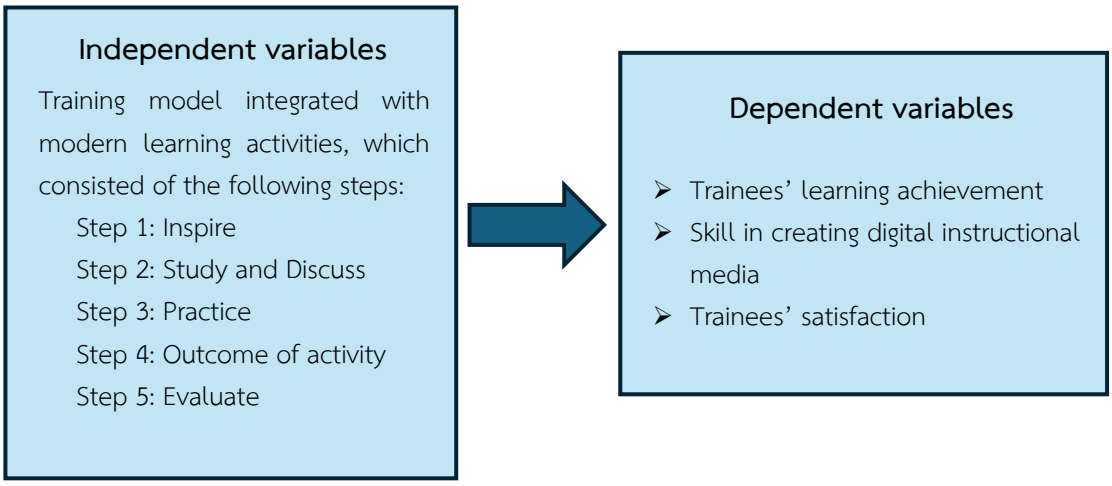

Figure 2: Conceptual framework in research

3.4 Research Instruments

The research instrument in this research consists of;

3.4.1 The modern learning activities and strengthening training model. The design of modern learning activities and strengthening training model, the strengthening training model was validated by seven experts. Their evaluations were analyzed using descriptive statistics, including the mean and standard deviation, to determine the quality and appropriateness of the model. Figure 3 shows the design of modern learning activities and the strengthening training model. The components of developing digital skills using modern learning activities in teaching and learning in the 21st century, the Thai teachers' competencies include 1) design of modern learning processes, 2) design of digital media which learning process in training is a workshop focusing using activity-based learning that consists of five steps (Sithsungnoen et al. 2022, pp. 89-110) as follows: 1) Inspire, 2) Study and Discuss,3) Practice, 4) Outcome of activity, and 5) Evaluate. At the end of the training process, Thai vocational teachers are expected to acquire three core competencies: 1) the ability to design modern learning processes, 2) the ability to create digital media, and 3) the ability to develop activity-based learning. The details of the training processes and activities are shown in Table 1.

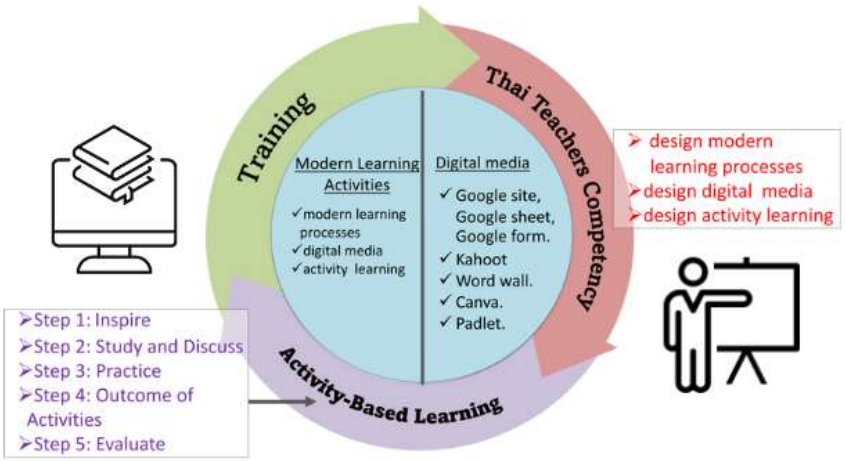

Figure 3: The design of modern learning activities and strengthening training model

Table 1 Training steps

Training Steps	Details of the training process	Training activities	Tool/ Media training
Step1: Inspire	Teachers motivate Step 1: Inspire teaching and learning, explain the purpose of the training, recall foundational knowledge to guide students into the desired content, create an environment that prepares learners for learning, and organize students into groups for assigned group activities.	Teacher - Create motivation. - Explain the purpose of the Training. - Recall knowledge. - Build a training. atmosphere. - Divide learners into groups. Learners - Listen to the Teacher. - Question and Answer with the teacher. - Take the pre-test.	Teacher - The training handbook. - Instruction media such as online media, real media, etc. Learners - The pre-test form.
Step 2: Study and discuss	Teachers present lessons that are challenging and engaging to learners, and the learners study the knowledge, provide feedback, and exchange opinions with peers in the group. Subsequently, discuss collectively to exchange viewpoints.	Teacher - Provide knowledge - Facilitate learners Learners - Divide tasks into groups. - Exchange ideas. - Discussion of results.	Teacher -The training handbook. - Instruction media such as online media, PowerPoint presentation. Learners - Content sheet. - Activity sheet.
Step3: Practice	Teachers facilitate activities by ensuring that every learner in each group actively participates, enabling learners to systematically apply problem-solving processes during the activities.	Teacher - Organize competitions for each activity. - Providing positive reinforcement to learners. - Facilitate learners. - Foster a conducive learning environment. Learners - To engage in practical work. - Solve problems systematically.	Teacher - The Training Handbook. - Digital skills assessment form. Learners - Content sheet. - Activity sheet. - Online media such as Kahoot, Canvas, Word Wall, etc.

Table 1 (continued) Training steps

Training Steps	Details of the training process	Training activities	Tool/ Media training
Step 4: Outcome of activity	All learner groups present their ideas and responses from the activities, and learners and instructors collaboratively discuss answers and verify accuracy together, reflecting on the thoughts and knowledge acquired from the activities.	Teacher - Discuss the answers. - Check and correct the answer. Learners - Presenting ideas and knowledge from activities. - Discuss the answers.	Teacher - The training handbook. - Online discussion boards such as Padlet. - Digital skills assessment form. Learners - Content sheet. - Activity sheet. - Online media such as Google Sites, etc.
Step 5: Evaluate	The teacher assesses the learning outcomes based on what students have learned and practised through group activities, to develop the learning process and make improvements in learning management	Teacher - Assess learning outcomes. Learners - Take the pre-test - Take the satisfaction assessment.	Teacher -The training handbook. Learners - Post-test form. - The satisfaction assessment.

3.4.2 The training handbook consists of a teacher's guide, training activity plan, content sheet, PowerPoint presentation, activity sheet, and achievement test. The training handbook was validated by seven experts. Their evaluations were analyzed using descriptive statistics, including the mean and standard deviation, to determine the quality and appropriateness of the training handbook.

3.4.3 The achievement test consists of a multiple-choice test of 40 points, the items and behavioural objectives passed the content validity from seven experts, found that the IOC (Item Objective Congruence) value range was 0.80–1.00 (the IOC value of 0.50 or higher is deemed consistent with the acceptable standards).

3.4.4 The evaluation forms for creating digital media with modern learning activities use a rubric-based assessment form with five scoring levels.

3.4.5 The trainee's satisfaction assessment with a five-point rating scale.

3.5 Data Collection

The researcher conducted the experiment following the research design using a training program that had been evaluated and validated for quality. The program was implemented with a sample group of 50 participants. The data collection process consisted of the following steps:

3.5.1 The researcher explained the training process to the participants.

3.5.2 Participants took a pre-test to measure their initial knowledge.

3.5.3 The training activities were conducted until all content was completed.

3.5.4 Participants took a post-test to measure what they had learned.

3.5.5 Participants completed a satisfaction questionnaire about the training.

3.5.6 Compiling and analyzing the collected data using appropriate statistical methods.

3.6 Data Analysis

3.6.1 The appropriateness of the suitability of the developed training model and learners' satisfaction was assessed using the mean and standard deviation. The interpretation of the results was based on the following rating scale (Yuangngoen et al., 2019, pp. 50-58):

Mean score between 4.50–5.00 = highest level
Mean score between 3.50–4.49 = high level
Mean score between 2.50–3.49 = moderate level
Mean score between 1.50–2.49 = low level
Mean score between 1.00–1.49 = lowest level

3.6.2 The comparison of results of the pre-post learning achievements using t-test for dependent statistics.

3.6.3 The creation of information technology media skills using mean and percentage statistics.

IV. RESULTS

4.1 The Suitability of the Developed Training Model

The suitability of the developed modern learning activities training model is displayed in Table 2.

Table 2 Suitability of the developed training model (n=7)

Item	$\bar{x}$	SD	Interpret
1. Training model	4.40	0.31	high
2. Training activities	4.60	0.19	highest
3. Media support training	4.49	0.30	high
4. Measurement and evaluation of training	4.31	0.22	high
Total average	4.45	0.19	high

Table 2 shows the results found that the suitability of the developed training model was at a high level ($\bar{x}$ = 4.45, SD = 0.19) by seven experts. The topics with the highest means of feedback were training activities ($\bar{x}$ = 4.60, SD = 0.19) and topics with the lowest means of feedback were measurement and evaluation ($\bar{x}$ = 4.31, SD = 0.22).

4.2 The Performance of Learning Achievement

The performance of learning achievement was measured by administering a pretest to 50 trainees, followed by implementing the training plan across all units. Afterwards, a 40-item posttest was conducted. The data were analyzed using a t-test to assess learning progress. The results of the analysis are presented in Table 3.

Table 3 Performance of learning achievement (n=50)

Test	Score	$\bar{x}$	SD	df	t_{cal}	Sig. (1 tailed)
Pretest	40	16.70	5.20	49	20.82*	0.0000
Posttest	40	30.24	2.89			

**p < .05, one-tailed*

Table 3 shows that the trainees' mean pre-test score was 16.70, while the mean post-test score increased to 30.24. A comparison between pre-test and post-test scores indicates a statistically significant improvement at the .05 level.

4.3 The Skill of Creating Information Technology Media

The trainees create digital media using the rubric standards of ten items as presented in Table 4.

Table 4 Performance of learning achievement

Item	$\bar{x}$ value (max 5 points)	Performance (100%)
1. Selection of modern media.	4.00	80.00
2. Arrangement element of modern media.	3.88	77.60
4. Presentation of developed media.	4.02	80.40
5. Details and accuracy of the media	3.64	72.80
6. Consistency between learning activities in the media	4.30	86.00
7. Learning activities promote learning in the media.	4.36	87.20
8. Learning activities attract interest.	4.16	83.20
9. Modernization of learning activities.	3.68	73.60
10. A variety of learning activities.	4.22	84.40
Total average	4.01	80.24

Table 4 shows that the overall creating information technology media skills of trainees were equal to 80.24% (equal to 4.01 of 5 maximum points) that trainees have a high competency. Participants showed strong competencies in designing engaging and coherent learning activities. However, aspects such as content accuracy and modernization of activities showed room for improvement.

4.4 Evaluation of Trainees' Satisfaction

The satisfaction in the training using the developed training model was evaluated using 50 trainees who were taught at the office of the Vocational Education Commission, Samut Sakhon Province, Thailand, as shown in Table 5.

Table 5 Evaluation of trainees' satisfaction (n=50)

Item	$\bar{x}$	SD	Interpret
Training activities	**4.51**	**0.26**	**highest**
1. Promote the use of various tools and technology.	4.68	0.47	highest
2. Encourage trainees to exchange ideas.	4.40	0.67	high
3. Trainees independently research and acquire knowledge on their own.	4.60	0.49	highest
4. Trainers think analytically and solve problems using training activities.	4.32	0.62	high
5. Training activities are diverse and promote knowledge and skills to improve the teaching and learning process.	4.54	0.50	highest

Table 5 (continued) Evaluation of trainees' satisfaction (n=50)

Item	$\bar{x}$	SD	Interpret
Instructional media for training	**4.39**	**0.24**	**high**
6. Encourage trainees to learn well.	4.52	0.50	highest
7. Instructional media is appropriate and consistent with the training.	4.04	0.73	high
8. Encourage students to learn step by step.	4.60	0.40	highest
9. Learn complex content faster.	4.38	0.60	high
10. Encourage learners to have a good attitude toward vocational education.	4.40	0.49	high
Measurement and evaluation	**4.15**	**0.29**	**high**
11. Measuring tools can evaluate knowledge, skills, and attitudes.	4.02	0.71	high
12. Measurement methods are diverse and consistent with the training model.	4.16	0.65	high
13. Assessments are diverse and consistent with the training model.	4.00	0.67	high
14. Evaluation criteria are clear and appropriate.	4.26	0.69	high
15. Collect data according to actual conditions from the trainers' learning.	4.30	0.46	high
Total average	4.34	0.17	high

Table 5 shows that the overall trainees' satisfaction is equal to 4.34 out of a maximum of five points, and the SD is equal to 0.17. Trainees rated the training activities. Particularly, the use of technology was highlighted as a key strength of the training model.

V. CONCLUSION AND DISCUSSION

The results of the evaluation on the appropriateness of the developed training model by seven experts revealed that the overall appropriateness was at a high level ($\bar{x}$ = 4.45, SD = 0.19). For the learning achievement of the trainees, it showed that the post-training scores were significantly higher than the pre-training scores at the .05 level (Pre-test = 16.70, Post-test = 30.24, $p < .05$), In item the evaluation of digital media creation skills among the participants revealed an average score of 4.01 out of 5, equivalent to 80.24%. The evaluation of participants' satisfaction with the developed training model was at a high level ($\bar{x}$ = 4.34, SD = 0.17). Based on these findings, it is recommended that vocational education policymakers adopt structured training programs that incorporate modern learning activities and digital skill development into professional training frameworks. Institutional support in terms of resources and digital tools should be ensured to foster sustainable skill advancement among vocational teachers.

The quality of the developed training model is at a high level because the researcher proceeded systematically with steps before being evaluated by experts, begins with studying data on training curriculum development, the principles of training, training objectives, training content, training methods, training materials, and evaluation, which are used to design training activities, this aligns with Tyler's research (Tyler, 1950, pp. 51-59) and (Taba, 1962, p. 12) which states that the curriculum consists of objectives, experiences/content, experiential organization, and evaluation, the results of the quality assessment of the training format align with Banjob Boonchan (Boonchan, 2016, pp. 186-206) discussed in the study on the development of a training curriculum on technology leadership for Master of Education Students in Educational Administration. It was found that the training curriculum has the highest level. The learning outcomes of the trainees increased significantly following the training model, this indicates

that the developed training model effectively enhanced the digital skills of vocational teachers due to training management emphasizes trainees integrating a variety of modern learning media activities, which allows the trainers to acquire knowledge, understanding, and skills appropriately, which aligns with the research of Phattarapan Nithiwaratsakut (Nithiwaratsakut et al., 2023, pp. 677-686) asserts that learning using digital technology as a tool to enhance learning effectively. Digital learning tools are programs or applications for individual learning, individually or in groups. Learning using digital technologies such as computer programs, online media, and applications that can be accessed with an internet connection via a computer or smartphone. tools to support their learning and make learning more effective. learn more, learn faster, learn more accurately and can be used more, take less time, etc. The trainees achieved more than 80% in digital media creation skills due to research evaluate the quality of the training management model appropriately and determine a sequence of steps for the training model that results in trainees learning and developing digital media in a connected and related sequence of steps while the average score for digital media creation exceeded 80%, four indicators scored lower: arrangement element (77.60%), design and beauty (77.20%), accuracy and detail (72.80%), and modernization of learning activities (73.60%). These results may stem from limited familiarity with visual hierarchy, insufficient skills in creative software, and lack of emphasis on content precision. Additionally, the relatively low modernization score suggests incomplete application of current pedagogical methods. These areas should be enhanced in future training through more targeted instruction on digital aesthetics, content accuracy, and innovative instructional strategies that aligns of Waruch Tantiwong (Tantiwong et al., 2023, pp. 68-82) found that integrating digital lesson creation with active learning supports systematic infographic production, including content gathering, revision for objective alignment, and use of clear, understandable video presentations to enhance digital learning material delivery. Therefore, the presentation of media is appropriate for the active learning management process. The activity conducted within digital classrooms helps promote knowledge acquisition among learners and promotes students' ability to create multimedia graphic works. The participants' satisfaction with the developed training model was at a high level due to the training process using step-by-step methods to help trainees develop digital instructional media, encouraging research, creativity, and self-directed learning. Activities align with practical applications, while instructors guide transformative learning through recommendations and support independent inquiry. However, it is worth noting that among the three satisfaction components, measurement and evaluation received the lowest average score, compared to training activities and instructional media, as shown in Table 5. This may suggest a need to improve the variety, clarity, and alignment of assessment tools with training objectives. Clearer criteria and more engaging evaluation formats could enhance this aspect in future iterations of the model which aligns with the research of Pattranit Promsurin (Promsurin, 2023, pp. 235-250) studying on the Training Curriculum Development on STEM Education Learning Management Design for Teachers in Learning Area of Health and Physical Education Nakhon Nayok Province found that the satisfaction of trainees were at the highest level. ($\bar{x}$ = 4.54). In addition, corresponds to the research of Afdol Awae (Awae et al., 2023, pp. 83-92) studying managing activity-based learning to enhance 21st-century skills of first-year students of Yala Rajabhat University found that the students' satisfaction towards the Life Skill for Society course was positive in every aspect–that the teacher attributes, the learning activities, and application. It was at a good level ($\bar{x}$ = 4.44, SD = 0.62) in overall view.

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

INTERNATIONAL JOURNAL of Industrial Education and Technology

ENHANCING THE 5 Cs THROUGH EIGHT HOLISTIC ACTIVE LEARNING PROCESSES: A STUDY OF ENGLISH PRESERVICE TEACHERS' LEARNING ACHIEVEMENT AND REFLECTIONS IN A 21ST-CENTURY SKILLS FOR LIFE AND CAREER COURSE

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Received: June 22, 2025 **Revised:** June 27, 2025 **Accepted:** June 30, 2025

Citation reference :
Kanchana, K. (2025). Enhancing the 5 Cs through eight holistic active learning processes: a study of english preservice teachers' learning achievement and reflections in a 21ST- century skills for life and career course. **International Journal of Industrial Education and Technology,** 7 (1), 72-84.

ABSTRACT

This retrospective mixed-methods study examined how eight holistic active learning processes enhanced the 5Cs (Contemplative Thinking, Critical Thinking, Communication, Collaboration, and Creative Thinking) among 29 English preservice teachers. The eight holistic active learning processes-BALANCE, INDARA+C, CLEAR, PEACE, CREATIVE, QUEST, GRACE, and MIRACLE-were implemented in a 21st Century Skills for Life and Career course. Tools for data collection consisted of achievement tests (140 points in total) and 263 weekly reflections over 14 weeks, analyzed using descriptive statistics and thematic coding. The English preservice teachers achieved very good overall performance (84.19%), with collaboration and creative thinking exceeding 90%. The application of skills to daily life increased progressively, from zero to 34 instances, with transformative experiences peaking during the GRACE and MIRACLE sessions. The English preservice teachers preferred interactive activities and requested more practice time. The findings support integrating contemplative education with active learning to develop 21st-century teacher competencies.

Keywords: Contemplative education, Holistic active learning, 21st century skills, Preservice teachers, 5Cs skills

I. INTRODUCTION

The rapid transformation of the 21st century demands a fundamental shift in education-from passive knowledge transmission to the development of essential competencies that enable learners to navigate an unpredictable future. The Organization for Economic Co-operation and Development (OECD, 2019, p. 7) emphasizes that education must help learners develop a "reliable compass" to face complexity and uncertainty. This imperative is particularly critical in teacher education, where future educators must acquire 21st-century skills-specifically, the 5Cs: Creativity and Innovation, Critical Thinking and Problem Solving, Communication, Collaboration, and Contemplative Thinking. These competencies represent core human abilities that distinguish individuals from technological automation and empower educators to design transformative learning experiences (World Economic Forum, 2023, pp. 38-39). Addressing this challenge, the "21st Century Skills for Life and Career" course is designed to cultivate these competencies among preservice teachers through an integrated curriculum that spans cognitive (understanding 21st-century society and the 5Cs), affective (developing teacher identity and professional responsibility), and psychomotor (applying skills in real-world contexts) domains. The course content includes global and Thai perspectives on 21st-century societal changes, essential skills frameworks, and practical applications, while instructors manage pedagogical tensions such as balancing theoretical understanding with experiential learning and integrating contemplative practices into active learning environments.

Recent empirical studies in Thai and regional teacher education consistently demonstrate the effectiveness of integrative approaches in fostering the 5Cs. Contemplative practices-such as mindfulness, deep listening, and visual reflection-have been shown to significantly enhance students' self-awareness, inner calm, and ethical sensitivity (Tanatpornpong & Nakorn, 2024, p. 59; Bodhisatirawaranggoora et al., 2024, p. 97). Critical thinking is promoted through inquiry-based learning, peer questioning, and reflective strategies (Surin & Damrongpanit, 2024, p. 1395; Namsaeng & Ambele, 2024, p. 75). Creative thinking is stimulated through active, digital, and project-based methods (Muñoz-Salinas et al., 2025, p. 2; Li & Tu, 2024, p. 2). Collaboration and communication are strengthened through cooperative lesson planning, peer mentoring, and intercultural training (Maghfiroh et al., 2025, p. 666; Boonmoh & Kulavichian, 2024, p. 124; Marasri, 2025, p. 62). However, significant gaps remain: no existing study has examined the simultaneous development of all five competencies within a single, integrated framework; contemplative education remains underexplored in teacher education research; and there is a lack of systematic models that connect multiple learning processes across extended periods.

This study introduces eight holistic active learning processes (BALANCE, INDARA+C, CLEAR, PEACE, CREATIVE, QUEST, GRACE, and MIRACLE) developed by the researcher as an innovative pedagogical framework designed specifically for the comprehensive development of the 5Cs. The framework is grounded in five key theoretical foundations: Contemplative Education underpins INDARA+C, GRACE, and PEACE by fostering inner awareness and emotional regulation (Zajonc, 2013, p. 83; Barbezat & Bush, 2014, p. 2); Constructivism supports BALANCE, CREATIVE, and QUEST through active knowledge construction (Office of the Education Council, 2020, pp. 18-21; OECD, 2019, pp. 7, 16); Social Learning Theory informs MIRACLE, PEACE, and QUEST through peer interaction and shared learning (Bandura, 1977, pp. 6, 22); Experiential Learning Theory contributes to BALANCE, CLEAR, and CREATIVE by emphasizing direct experience and reflection (Kolb, 1984, p. 41); and Transformative Learning Theory forms the basis of GRACE, CREATIVE, and QUEST through critical reflection and perspective transformation (Mezirow, 1997, p. 5; Jarvis, 2009, p. 25). Each process is intentionally aligned with particular competencies while concurrently supporting the broader dimensions of the 5Cs framework.

These theoretical underpinnings and their integration into each learning process are examined in detail in the literature review section.

The aim of this research is to investigate the effectiveness of eight holistic active learning processes in enhancing 5Cs skills among English preservice teachers, using a mixed-methods approach. Specifically, the study examines preservice teachers' learning achievement after participating in these processes within a 21st-century skills course, analyzes their reflective thinking on 5Cs development through weekly reflections, and explores their suggestions for course improvement. By integrating quantitative achievement data with qualitative reflections over a 16-week period, this study offers comprehensive insights into how contemplative education, when combined with active learning, can equip future teachers with essential competencies required to navigate and shape education in the 21st century.

II. LITERATURE REVIEW

Recent research in teacher education has increasingly focused on developing multiple competencies simultaneously, although comprehensive and integrative frameworks remain limited. Studies on contemplative practices in education demonstrate significant impacts on self-awareness, emotional regulation, and ethical development. Tanatpornpong and Nakorn (2024, p. 59) found that mindfulness-based practices enhanced Thai preservice teachers' self-awareness and stress management, while Bodhisatirawaranggoora et al. (2024, p. 97) showed that visual contemplative practices fostered deeper reflection and aesthetic sensitivity. Critical thinking development has been extensively studied through active learning approaches. A meta-analysis by Surin and Damrongpanit (2024, p. 1395) revealed that peer questioning strategies significantly improved critical thinking, with effect sizes ranging from moderate to large. Research on creative thinking indicates positive outcomes from project-based and digital learning methods (Li & Tu, 2024, p. 2), although Muñoz-Salinas et al. (2025, p. 2) highlight persistent conceptual ambiguities in defining creativity within Southeast Asian educational contexts. Collaborative competencies have been enhanced through structured peer interactions, with Maghfiroh et al. (2025, p. 666) demonstrating how peer mentoring in lesson planning fostered both collaboration and professional identity. Research on communication emphasizes the importance of authentic contexts and intercultural competence (Boonmoh & Kulavichian, 2024, p. 124; Marasri, 2025, p. 62). However, most studies address these competencies in isolation, overlooking the potential synergies of integrated development. Theoretical foundations for holistic learning draw upon multiple paradigms: Contemplative Education emphasizes inner awareness and wisdom (Zajonc, 2013, p. 83; Barbezat & Bush, 2014, p. 2); Constructivism promotes active knowledge construction (OECD, 2019, p. 16); Social Learning Theory highlights collaborative knowledge building (Bandura, 1977, p. 22); Experiential Learning emphasizes reflection-action cycles (Kolb, 1984, p. 41); and Transformative Learning fosters perspective transformation (Mezirow, 1997, p. 5). Together, these theories support integrated approaches that simultaneously engage cognitive, affective, and behavioral dimensions of teacher development.

Building on these theoretical and empirical foundations, this study hypothesizes that eight holistic active learning processes (BALANCE, INDARA+C, CLEAR, PEACE, CREATIVE, QUEST, GRACE, and MIRACLE) can effectively enhance all 5Cs competencies when implemented systematically over an extended period. Each process, while grounded in primary theoretical foundations, incorporates elements from all five theories as complementary frameworks. For instance, BALANCE primarily draws from Experiential Learning and Constructivism but incorporates contemplative elements in Base Exploration, social learning in Networking, and transformative reflection in Evaluation stages. Similarly, INDARA+C, though rooted in Contemplative Education, utilizes constructivist knowledge building, social sharing circles, and experiential application activities. This multi-theoretical integration ensures that each process, regardless of its primary focus, contributes to holistic development across all 5Cs competencies. The study posits that this integrated framework addresses the limitations of single-competency approaches by creating synergistic learning experiences where multiple competencies are developed simultaneously. The 16-week implementation period allows for deep engagement and skill transfer, while the mixed-methods approach captures both quantitative achievement and qualitative transformation. This research thus examines whether holistic active learning processes can prepare preservice teachers with the full spectrum of 21st-century competencies needed for educational leadership in an uncertain future.

III. RESEARCH METHODOLOGY

This study employed a retrospective embedded mixed-methods design, in which qualitative data from weekly reflections served as the primary source for understanding students' development of 5Cs competencies throughout the 16-week course. Quantitative assessments were strategically embedded at midterm (Week 9) and final (Week 16) to measure learning achievement and triangulate the qualitative findings.

Participants were 29 second-year preservice English teachers enrolled in the required 21st Century Skills for Life and Career course. Data were collected during the second semester of the 2024 academic year at a teacher education institution in southern Thailand. After final grades had been submitted and students informed of their results, the researcher sought consent through the class LINE group application. All participants were informed of the research purpose and were given the option to decline participation by sending a private message. None declined, resulting in full consent. This post-hoc consent procedure ensured that participation was voluntary and uninfluenced by academic evaluation.

Weekly reflection submissions varied between 17 and 26 participants, reflecting the voluntary nature of these assignments during the original course implementation.

Figure 1 presents the conceptual framework, illustrating how theoretical foundations were integrated into the learning processes and linked to measurable outcomes.

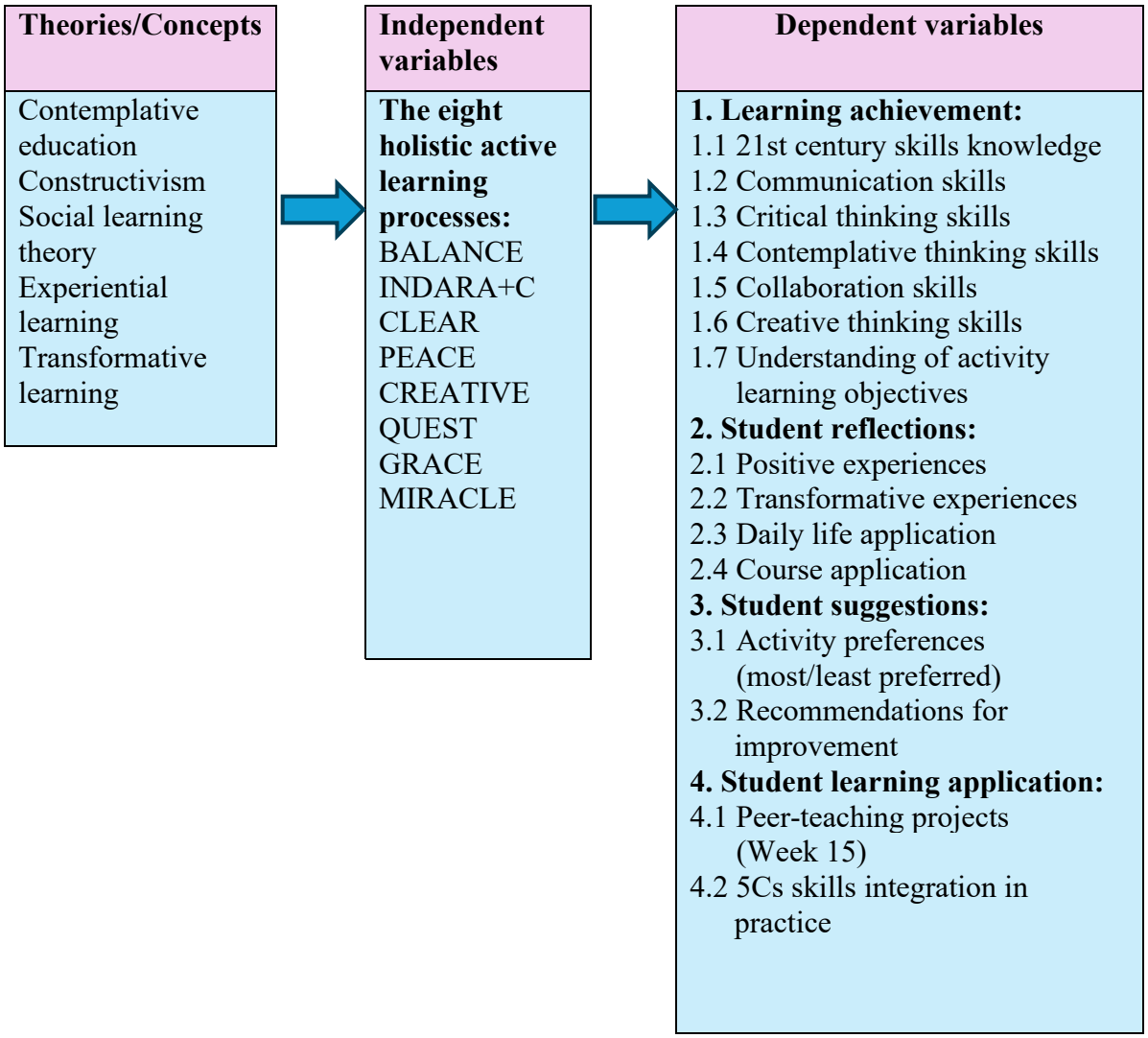

Figure 1: Conceptual framework for enhancing 5Cs skills through eight holistic active learning processes

Eight holistic active learning processes were implemented over 14 instructional weeks, excluding Weeks 1 (orientation), 9 (midterm examination), 15 (peer teaching projects), and 16 (final examination). Each process was designed to develop specific dimensions of the 5Cs competencies-communication, critical thinking, contemplative thinking, collaboration, and creative thinking-through structured pedagogical sequences aligned with relevant theoretical foundations and intended learning outcomes.

BALANCE (Weeks 2–3) focused on building foundational understanding and promoting balance through seven structured steps: Base Exploration (preparing the body and mind), Acquiring Knowledge (connecting new knowledge with prior experiences), Learning by Doing (hands-on activities), Application (solving real-world problems), Networking (peer exchange and discussion), Critical Reflection (thoughtful review), and Evaluation (authentic assessment). Key learning activities included practical and collaborative tasks, such as Brain Gym exercises, comparative analysis of the WEF and P21 frameworks, the Clock Game, News Reporter interviews, community problem-solving through village design using Canva, “Truth or Lie” storytelling, gesture-based games, and role-playing performances.

INDARA+C (Week 4) emphasized internal insight and self-awareness through seven reflective and experiential steps: Insight (self-discovery through the "Mirror of the Heart" activity), Nurturing Knowledge (learning the 5Cs framework), Deep Listening (sharing meaningful life stories with non-judgmental peer listening), Awareness (exploring internal and external dimensions of the self through the "Iceberg Activity"), Reflection (deep contemplation integrated throughout the learning process), Application (understanding and managing emotions through activities such as card stacking and emotion guessing), and Check-Out (structured reflection questions on learning, emotional experience, and areas for improvement).

CLEAR (Weeks 5-6) developed clear communication through five structured steps: Comprehend (analyzing video clips of effective and ineffective communication and sharing personal experiences), Learn (studying communication elements, dimensions, and types through group presentations), Exercise (role-playing communication scenarios and producing communication videos), Apply (implementing communication strategies in group tasks and daily interactions), and Reflect (completing weekly Padlet reflections by responding to five to six guided questions about learning and communication skill development).

PEACE (Week 7) introduced peaceful communication grounded in the principles of Nonviolent Communication through five sequential phases: Preparation (grounding activities to center attention), Engagement (sharing personal communication experiences), Acquisition (learning the core components of Nonviolent Communication), Collaborative Learning (practicing skills in groups), and Expression (sharing reflections and insights). The "Giraffe-Wolf" activity was used to contrast compassionate and aggressive communication styles.

CREATIVE (Week 8) fostered creative problem-solving through an eight-step innovation process: Contemplation (identifying relevant problems), Realization (understanding the root causes), Exploration (researching alternative solutions), Analysis (evaluating options), Transformation & Innovation (developing creative prototypes), Implementation (testing and applying solutions), Verification (gathering feedback from peers), and Evolution/Evaluation (refining approaches based on reflection and results).

QUEST (Week 10) enhanced critical thinking through five progressive steps: Question (formulating meaningful inquiries), Understand (analyzing contextual factors and underlying assumptions), Evaluate (assessing alternative perspectives and potential solutions), Summarize (synthesizing key insights), and Transfer (applying learned concepts to new situations). Key learning activities included analyzing fake news articles and designing decision-making frameworks to support evidence-based reasoning.

GRACE (Weeks 11-12) cultivated self-compassion and meaningful interpersonal connection through five reflective and experiential phases: Ground Yourself (using the L-O-V-E framework: Loving Practice, ORS Process [Observe–Reflect–Share], Vision, Engagement, and Essential Learning); Ritualize and Relate (creating safe and trusting spaces for authentic sharing); Act with Compassionate Awareness (engaging in empathetic actions); Create Meaningfully (expressing insight through mandala creation); and Express and Reflect (sharing personal insights and synthesizing learning experiences).

MIRACLE (Weeks 13–14) built collaboration skills through seven interconnected phases: Motivation (inspiring teamwork and collective purpose), Inspiration (sharing success stories to foster shared vision), Royal Speeches (grounding collaborative values in ethical and cultural principles), Active Lecture (engaging students through interactive input), Collaboration (participating in team-based learning activities), Learning Reflection (processing group experiences and insights), and Experiential Insight (gaining personal realizations through shared learning).

Student-led projects applying the CREATIVE framework (Week 15) featured student-designed innovative teaching projects that addressed real-life challenges faced by their classmates using the CREATIVE framework. The process followed eight integrated steps: Contemplation (reflecting on authentic peer challenges), Realization (identifying and understanding the root causes), Exploration (researching potential solutions and pedagogical approaches), Analysis (evaluating instructional strategies), Transformation & Innovation (designing targeted learning activities), Implementation (conducting peer teaching sessions), Verification (gathering peer feedback), and Evolution/Evaluation (reflecting on the teaching experience and participant responses). This culminating activity enabled students to meaningfully apply the 5Cs competencies in authentic, student-centered teaching contexts.

Quantitative data were collected through seven post-test topics (20 points each; 140 points in total) using proctored Google Forms administered in classroom settings during the midterm and final examinations. Each assessment consisted of multiple-choice questions with four answer options per item. The midterm examination assessed students' understanding of 21st-century skills, creative thinking (Guilford's divergent thinking and Torrance's components), and communication skills (active listening, nonviolent communication, and cross-cultural competence). The final examination evaluated collaboration skills (team effectiveness, trust-building, and conflict management), understanding of learning objectives, critical thinking (10 items, 2 points each), and contemplative thinking (mindful awareness, self-empathy, and reflective practices). Descriptive statistics, including means, standard deviations, and percentages, were calculated using Microsoft Excel to analyze students' achievement levels across the targeted competencies.

Qualitative data consisted of 263 weekly reflections collected via Padlet during Weeks 2-8 and 10-14. For Weeks 2-5, students responded to five reflection prompts: (1) Which 21st-century skills (5Cs) did you develop through today's activities, and how? (2) How did you feel about today's learning process? (3) Which activity did you enjoy most, and why? (4) Which activity did you enjoy least, and why? (5) What skills do you need to improve, and how will you develop them? From Week 6 onward, a sixth question was added: "How can you apply today's learning to your daily life or other contexts?"- aimed at capturing skill transfer and real-world application.

Qualitative analysis employed manual coding based on a four-dimension analytical framework: positive experiences, transformative experiences, daily life application, and course application. The coding framework was validated by three education experts, each holding a doctoral degree and possessing extensive experience in teacher education. The researcher conducted all initial coding, while one expert reviewed the coding of Week 3 reflections to ensure interpretive consistency. Ongoing consultations with the expert panel throughout the analysis process contributed to the overall reliability of the coding procedure.

Data integration occurred during the interpretation phase, where quantitative achievement scores were compared with qualitative themes to identify convergent patterns and relationships. For example, high achievement in collaboration (91.21%) was interpreted alongside reflection data indicating frequent mentions of teamwork and peer support during the MIRACLE sessions. This embedded design enabled ongoing monitoring of skill development while providing objective measures to corroborate qualitative insights.

Trustworthiness was enhanced through multiple strategies: data triangulation, audit trail maintenance, member checking of interpretive summaries with selected participants, and reflexive journaling by the researcher throughout the analysis process.

Limitations and ethical considerations: Due to its retrospective design, this study could not establish causal relationships, as no control group or pre-test data were available. The dual role of the instructor-researcher posed a risk of bias, which was addressed through reflexive journaling and peer consultation. Although inter-rater reliability testing was not conducted for qualitative coding due to resource limitations, ongoing expert consultation helped ensure interpretive consistency. The small, homogenous sample-29 English preservice teachers from a single institution-limits the generalizability of the findings. Voluntary participation in weekly reflections may have introduced response bias, as more engaged students were likely to contribute. Moreover, the use of multiple-choice assessments may have inadequately captured the depth of 21st-century competencies, especially in critical and contemplative thinking. The 16-week course duration also prevented the assessment of long-term skill retention. While formal ethical approval was not required due to the study's retrospective nature, all ethical protocols were upheld, including informed consent, voluntary participation, and anonymization of data.

IV. RESULTS

Analysis of data from 29 preservice English teachers revealed the following findings:

Table 1: Post-test achievement scores (n=29)

Assessment components	Mean/20	SD	%	Level
5Cs skills				
Communication	15.34	2.26	76.72	Good
Critical thinking	14.90	1.94	74.48	Good
Contemplative thinking	17.93	1.68	89.66	Very good
Collaboration	18.24	0.86	91.21	Excellent
Creative thinking	18.10	1.67	90.52	Excellent
Foundation knowledge				
21st Century skills knowledge	16.28	2.78	81.38	Very good
Understanding of activity objectives	17.07	1.70	85.34	Very good
Total (140 points)	**117.86**	**-**	**84.19**	**Very good**

Note: Achievement levels: Excellent = 90-100% (18-20 points), Very good = 80-89% (16-17.9 points), Good = 70-79% (14-15.9 points), Fair = 60-69% (12-13.9 points), Needs Improvement = Below 60% (<12 points).

Students achieved very good overall performance ($\bar{X}$ = 117.86, 84.19%), with collaboration (91.21%) and creative thinking (90.52%) reaching excellent levels. The highest variance was observed in foundational knowledge of 21st-century skills (SD = 2.78), indicating greater individual differences in theoretical understanding. One student who demonstrated outstanding collaboration reflected: "*I finally understand that real teamwork isn't just dividing tasks, but truly listening and building on each other's ideas"* (Student 15, Week 13).

Table 2: Number of students who submitted reflections each week

Week	W2	W3	W4	W5	W6	W7	W8	W10	W11	W12	W13	W14	Total
Number of students	26	26	20	24	22	25	18	24	20	21	20	17	263

Note. Variations in weekly submissions reflect the voluntary nature of the reflection activity and contextual learning conditions. For instance, Week 8 immediately preceded the midterm examination period, and Week 14 marked the final teaching session led by the researcher before the exams. A few students were absent due to illness or personal commitments, while others attended class but chose not to submit reflections.

Table 3: Reflection analysis by learning process

Categories	BAL (W2-3)	IND+C (W4)	CLE (W5-6)	PEA (W7)	CRE (W8)	QUE (W10)	GRA (W11-12)	MIR (W13-14)	Total
Positive experience	70	20	40	22	18	19	38	37	264
Transformative experience	12	19	26	12	10	17	31	31	158
Daily life application	0	8	27	17	13	23	34	32	154
Course application	68	20	10	8	17	5	41	17	186

Note: BAL=BALANCE, IND+C=INDARA+C, CLE=CLEAR, PEA=PEACE, CRE=CREATIVE, QUE=QUEST, GRA=GRACE, MIR=MIRACLE. Numbers represent frequency of coded reflection instances in each category.

Daily life application increased from zero during BALANCE to 34 during GRACE. Transformative experiences peaked during GRACE and MIRACLE sessions (n=31 each). Examples of transformative experiences during GRACE sessions included: *"The mandala activity made me realize I've been too hard on myself. I learned self-compassion isn't weakness"* (Student 8, Week 11). Another student reflected: *"Sharing in the circle without judgment changed how I see my classmates—we all struggle with similar fears"* (Student 23, Week 12).

Table 4: Activity preferences summary

Process	Most preferred	Least preferred	Main suggestion
BALANCE	Clock game, Role play	Theory comparison	More activity time
INDARA+C	Iceberg activity	Card stacking	Reduce lecture time
CLEAR	Videos, Kahoot	Presentations	More practice time
PEACE	Empathy cards	Making slides	Reduce presentation frequency
CREATIVE	Banana menu	Fishbone diagram	More completion time
QUEST	Human knot	Cause-effect diagram	Better time management
GRACE	ORS, Mandala	Few/None	Consider environment
MIRACLE	Village protection	Royal speeches searching	Provide royal speech examples directly

Students consistently expressed a preference for interactive activities, frequently describing them as "fun and engaging" (mentioned 45 times), involving "learning by doing" (38 times), and allowing them to "work with friends" (32 times). In contrast, theory-based activities were less preferred, often perceived as involving "too much information" (28 times) or being "difficult to understand" (22 times). One student reflected: *"The Clock Game was amazing because we moved, laughed, and learned time management without realizing it"* (Student 4, Week 2). Conversely, another remarked: *"Comparing theories felt like reading a textbook-too abstract without real examples"* (Student 19, Week 3).

Table 5: Week 15 Student projects and 5Cs skills integration

Team (n)	Theme	Sample activities	5Cs skills focus	Key outcome
1 (10)	Love	Blossom & Brush, Mug & Hug	Collaboration, Creative thinking	"Applied collaboration in daily life"
2 (10)	Emotions	EMUTION*, Deep Talk	Communication, Critical thinking	"Learned to deal with emotions"
3 (9)	Health	Brain Gym, You are what you eat	Contemplative thinking, Critical thinking	"Reviewed eating habits through contemplation"

Note: *EMUTION is a student-created fortune-telling activity combining emotional themes with spiritual symbols.

Table 5 presents student-designed projects conducted in Week 15, which served as the culminating activity for integrating the 5Cs skills through team-based learning. Each team selected a meaningful theme (e.g., love, emotions, health) and created interactive activities to apply their knowledge in authentic, practical contexts.

Team 1 focused on emotional bonding and creativity through art-based activities; Team 2 designed tools for emotional expression and peer dialogue; and Team 3 explored health awareness through mindful reflection and critical analysis. These projects reflect students' ability to co-create engaging learning experiences while demonstrating mastery in selected 5Cs skills.

The students' reflections revealed a strong sense of ownership and relevance. For example, one student remarked, "After the Brain Gym, I realized I've never paid attention to what I eat or how it affects my energy" (Student 12, Week 15), while another shared, "Deep Talk helped me open up emotionally, something I've always avoided" (Student 17, Week 15). Such insights underscore the transformative and practical value of student-led learning.

Skills development pattern

The frequency of 5Cs skills mentioned in student reflections across the eight learning processes is illustrated in Figure 2**.**

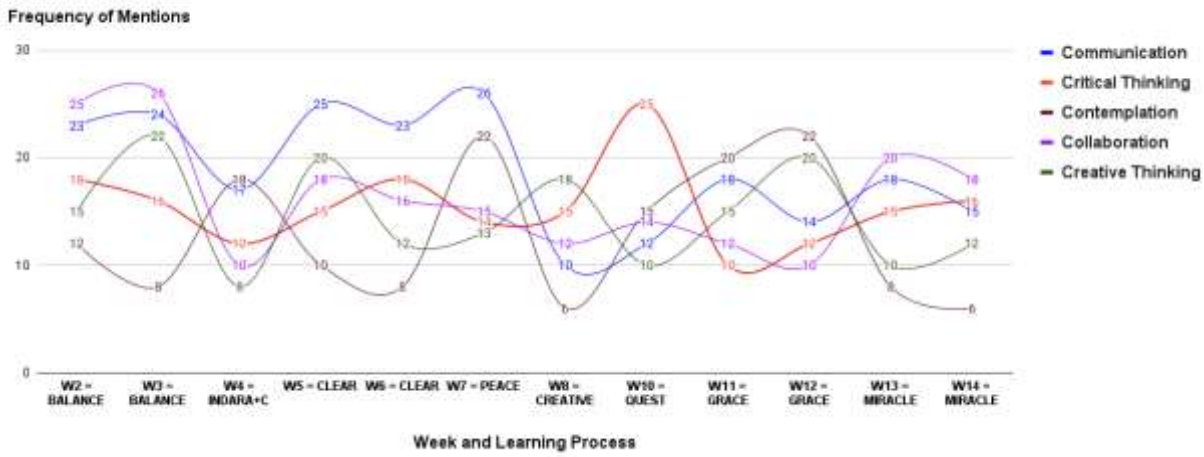

Figure 2: Development of 5Cs skills across 12 weeks by learning process

Communication and collaboration exhibited consistently high frequencies across all learning processes. Contemplative thinking notably increased during the INDARA+C (Week 4) and GRACE (Weeks 11-12) sessions. Creative thinking peaked during the CREATIVE process (Week 8), while critical thinking reached its highest frequency during QUEST (Week 10).

V. CONCLUSION AND DISCUSSION

This study examined the enhancement of 5Cs skills through eight holistic active learning processes among 29 preservice English teachers. Students demonstrated very good overall performance (84.19%), with collaboration (91.21%) and creative thinking (90.52%) reaching excellent levels, while communication (76.72%) and critical thinking (74.48%) remained at good levels. Analysis of 263 weekly reflections revealed progressive skill development, with daily life application rising from zero during BALANCE to 34 instances during GRACE sessions. Transformative experiences peaked during GRACE and MIRACLE sessions (n = 31 each), despite lower submission rates in Weeks 8 and 14. Students consistently preferred interactive activities over theoretical components, frequently requesting more hands-on practice time. The Week 15 peer-teaching projects showcased successful integration of all 5Cs, as teams creatively addressed real-life problems related to love, emotions, and health. These findings confirm the effectiveness of the eight holistic processes in cultivating integrated 21st-century competencies among preservice teachers.

The differentiated achievement levels reflect complex interactions between pedagogical approaches, skill characteristics, and cultural contexts. Collaboration and creative thinking excelled because these skills were embedded in every process from Week 2-14, aligned with Thai collectivist culture valuing group harmony, and utilized enjoyable experiential activities that students described as “fun and engaging” (45 mentions). These findings support constructivist (Kolb, 1984, p. 41) and social learning theories (Bandura, 1977, p. 22) emphasizing experiential and collaborative learning. Conversely, communication and critical thinking faced barriers as students found theoretical content “too much information” and expressed cultural discomfort with questioning peers-essential for critical thinking but conflicting with Thai values of maintaining

social harmony. This aligns with transformative learning challenges in collectivist contexts (Mezirow, 1997, p. 5). The lower submissions in Weeks 8 and 14, coinciding with complex analytical tasks and semester-end fatigue, paradoxically produced the highest transformative experiences, suggesting depth matters more than participation rates. Figure 2 reveals non-linear skill development patterns, with contemplative thinking peaking during INDARA+C and GRACE sessions incorporating mindfulness practices (Barbezat & Bush, 2014, p. 2; Zajonc, 2013, p. 83). Unlike previous research examining individual competencies separately (Surin & Damrongpanit, 2024, p. 108; Li & Tu, 2024, p. 119), this integrated approach demonstrates synergistic effects while highlighting cultural considerations essential for 21st-century teacher education (OECD, 2019, p. 7; World Economic Forum, 2023, p. 6). Future research should employ parallel group designs comparing variations of the eight processes, avoiding ethical concerns of non-intervention control groups while examining optimal combinations for diverse cultural contexts.

SUGGESTION

This retrospective classroom research revealed the potential effectiveness of eight holistic active learning processes in developing 5Cs skills among preservice English teachers, offering valuable insights for educational reform. Based on these promising results, several recommendations emerge for practice and future research. For immediate classroom implementation, educators should prioritize interactive, hands-on activities that engage students across multiple learning dimensions. The finding that students consistently preferred experiential activities while requesting "more practice time" suggests restructuring courses to minimize lecture-heavy sessions. Each learning process should incorporate collaborative elements, as these naturally foster creative thinking while aligning with collectivist cultural values. For culturally challenging competencies like critical thinking, educators should employ progressive scaffolding-beginning with neutral topics before advancing to peer evaluation-creating psychologically safe spaces where students can develop analytical skills without violating cultural norms of harmony. Future research should focus on transforming these eight processes into a validated pedagogical model through systematic Research and Development (R&D). The immediate next phase should employ prospective designs with parallel groups where two student cohorts experience different combinations or sequences of the processes, addressing ethical concerns of non-intervention control groups while enabling comparative effectiveness studies. This R&D approach allows the instructor-researcher to compare outcomes between variations, identifying optimal configurations. The development process should include creating standardized assessment rubrics that capture integrated competency development, refining instructional sequences based on comparative data, and establishing clear implementation guidelines derived from both groups' experiences. The R&D cycle should prioritize refining successful processes (GRACE and MIRACLE) while strengthening challenging areas like critical thinking development. Immediate tasks include creating comprehensive lesson plans, detailed facilitator guides, and formative assessment tools to track skill progression. The validated model should feature flexible modules integrable into existing courses without curriculum overhaul. Documentation must capture both successes and challenges, forming a living repository that can guide teacher education programs across Southeast Asia in developing culturally responsive frameworks for 21st-century competencies.

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DEVELOPING A TECHNOLOGY-ENHNCED FLIPPED CLASSROOM MODEL TO PROMOTE CREATIVE PROBLEM-SOLVING SKILLS IN UNDERGRADUATE EDUCATION: AN ANALYSIS OF CURRENT CONDITTIONS AND CHALLENGES

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Received: June 24, 2025 **Revised:** June 27, 2025 **Accepted:** June 29, 2025

Citation reference :
Kongpiboon, W., Sovajassatakul, T., & Petsangsri, S. (2025). Developing a technology-enhnced flipped classroom model to promote creative problem-solving skills in undergraduate education: an analysis of current conditions and challenges. **International Journal of Industrial Education and Technology,** 7 (1), 85-101.

ABSTRACT

The rapid evolution of digital technologies and shifting pedagogical paradigms have underscored the need for innovative learning models in higher education, particularly in fields that require applied problem-solving competencies. This study examines the current conditions, challenges, and development guidelines for a technology-enhanced flipped classroom learning model designed to foster creative problem-solving skills among undergraduate students in industrial vocational programs. Grounded in the Input–Process–Output (IPO) framework, the research addresses three primary objectives: (1) to analyze the existing teaching practices and instructional challenges faced by university instructors that affect students' creative problem-solving development; (2) to examine student perspectives and learning behaviors that influence the flipped classroom model's effectiveness; and (3) to propose development guidelines for an effective flipped classroom model that enhances students' creative problem-solving abilities-a total of 215 participants including university instructors and undergraduate students were selected using stratified random sampling. Data were collected through a five-point Likert scale questionnaire with strong content validity (CVI ranging from 0.80 to 1.00) and high internal consistency (Cronbach's alpha = 0.93). The study was conducted in three phases. Phase 1 analyzed the current instructional conditions and problems of instructors; Phase 2 investigated student opinions and learning behaviors; and Phase 3 assessed behavioral learning data in the Digital Photography Technology course. The findings provide an evidence-based foundation for developing a structured, technology-driven flipped classroom model tailored to enhance creative problem-solving skills within the context of higher education and work-integrated learning environments.

Keywords: Flipped classroom, Creative problem-solving, Technology-enhanced learning, Work-integrated learning, Instructional design

I. INTRODUCTION

In recent years, many countries worldwide have developed educational strategies that emphasize inclusivity and equity, aiming to ensure lifelong access to quality learning for all. These efforts align with the United Nations' Sustainable Development Goals (SDGs 2030), which influence global labor market demands that increasingly prioritize future-oriented skills such as analytical thinking, creative problem-solving, and the ability to collaborate effectively with others (World Economic Forum, 2024, online). Amid the complexity and volatility of the modern world characterized by the BANI (Brittle, Anxious, Nonlinear, and Incomprehensible) framework education systems must adapt their instructional approaches to equip learners with competencies responsive to these dynamic transformations (UNESCO, 2015, pp. 113-114). In Thailand, this imperative is particularly salient, given the country's 20-Year National Strategy (2017-2037) and its participation in regional economic cooperation. As a result, there is an urgent need to accelerate human capital development in alignment with the evolving demands of the industrial sector.

In recent years, higher education and vocational education have introduced innovative instructional approaches, such as active learning and student-centered learning, emphasizing learner engagement and the development of higher order thinking skills. However, most learning models still lack a systematic integration of technology into teaching and learning processes. Moreover, these approaches are often disconnected from real-world workplace contexts, resulting in suboptimal development of students' creative problem-solving skills and falling short of the intended learning outcomes (Kahiigi et al., 2011, pp. 338-346).

The flipped classroom model is an internationally recognized instructional innovation that emphasizes student-centered learning by encouraging learners to study foundational content independently outside the classroom, while using in-class time for activities that promote analytical thinking, discussion, and creative problem-solving (Bergmann & Sams, 2012, pp. 35-50; Tucker, 2020, pp. 7-8). This approach fosters greater student engagement and transforms the role of instructors from knowledge transmitters to facilitators of learning. However, the development and implementation of flipped classroom models in Thailand remain limited, particularly in terms of systematically integrating technology to effectively support the development of creative problem-solving skills. Therefore, there is a lack of empirically grounded, context-specific instructional models designed to meet the needs of Thai higher education institutions collaborating with industry (Mulder, 2017, pp. 739-742).

This research presented three objectives as follows: The first objective is to examine the current instructional conditions and challenges faced by university instructors that influence the development of students' creative problem-solving skills. The second objective is to investigate students' opinions and learning behaviors that affect the effectiveness of the flipped classroom model. Lastly, the objective is to propose development guidelines for an effective technology-enhanced flipped classroom model in the context of Thai higher education. This research aims to investigate and develop a technology-enhanced flipped classroom learning model that fosters creative problem-solving skills in undergraduate students.

II. LITERATURE REVIEW

In the context of higher education in Thailand, the Thai Qualifications Framework for Higher Education (TQF: HEd) was developed to enhance the quality of tertiary education by establishing a structured progression of qualification levels and specifying learning outcome standards across five core domains: ethics and moral reasoning, knowledge, cognitive skills, interpersonal skills and responsibility, and numerical analysis, communication, and information technology skills. However, the implementation of TQF: HEd continues to face challenges, particularly in the assessment and evaluation of student learning outcomes, most notably in the area of creative problem-solving skills, which are considered critical for success in the 21st century.

Instructional System Design (ISD) plays a crucial role in developing effective teaching and learning processes. One of the most widely accepted frameworks in this domain is the ADDIE model, which consists of five key phases: Analysis, Design, Development, Implementation, and Evaluation. In addition to ADDIE, other well-established models such as those proposed by Dick and Carey, Morrison, Ross, Kemp and Kalman, and Gerlach and Ely emphasize systematic instructional design tailored to specific learning contexts (Dick & Carey, 2015, pp. 218-243; Gerlach & Ely, 1980, pp. 200-238; Kemp et al., 2011, pp. 136-155; Morrison et al., 2001, pp. 79-83). Within the context of flipped classroom learning, which emphasizes self-directed study outside the classroom and uses in-class time for higher-order thinking activities and peer interaction, instructional system design is supported by the strategic integration of digital resources to promote creative problem-solving skills. In this regard, the conceptual frameworks of (Paul & Elder, 2006, pp. 19-22) highlight key elements of creative problem-solving, including problem identification, hypothesis formulation, experimentation, and the generation of novel and contextually appropriate solutions.

III. RESEARCH METHODOLOGY

This study focuses on the development of a technology-enhanced flipped classroom learning model designed to foster creative problem-solving skills among undergraduate students. The study integrates three key frameworks: the Instructional System Design (ISD) model-comprising Input, Process, Output, and Feedback components; the Thai Qualifications Framework for Higher Education (TQF: HEd); and the flipped classroom approach, which emphasizes self-directed learning outside the classroom and the use of in-class time for analytical thinking, collaborative problem-solving, and knowledge co-construction. Furthermore, the study incorporates the theoretical foundations of (Paul & Elder, 2006, pp. 19-22) to inform both the design process and data analysis, particularly in relation to fostering creativity and innovation.

The research targets two main participant groups: university instructors and undergraduate students. In Phase 1, purposive sampling was used to select five instructors from the School of Industrial Education and Technology at King Mongkut's Institute of Technology Ladkrabang. The selected instructors had over three years of teaching experience in the Digital Photography Technology course. In Phase 2, the target population included 450 undergraduate students who had previously taken the same course in the second semester of the 2023 academic year. Based on Yamane formula (Yamane, 1973, pp. 368-391) the sample size was determined to be 215 students, selected through stratified random sampling.

The research process was divided into two main phases. Phase 1 focused on investigating the current conditions and challenges in instructional management. Data was collected through a structured interview protocol developed based on a review of related theories and frameworks, including the TQF: HEd, ISD, flipped classroom learning, and creative problem-solving. The interview consisted of four sections: (1) respondent demographics, (2) current teaching challenges, (3) in-depth questions aligned with ISD components, and (4) recommendations for developing an instructional model. Data were analyzed using content analysis via ATLAS.ti 7™, which facilitated keyword extraction and thematic categorization. Phase 2 investigated students' opinions and learning behaviors using a questionnaire developed from Phase 1 findings. The instrument included four sections: (1) respondent demographics, (2) 25 items on teaching challenges in the Digital Photography Technology course, (3) 18 items measuring learning behavior, and (4) open-ended suggestions. Instrument quality was assessed using the Index of Item-Objective Congruence (IOC), with values ranging from 0.80 to 1.00. Reliability was confirmed using Cronbach's Alpha, yielding coefficients of 0.97 and 0.93 for the respective scales.

Data collection was conducted in person between November 4 and 20, 2023, and all 215 questionnaires were returned, representing a 100% response rate. The data were analyzed using descriptive statistics, including mean, standard deviation, frequency, and percentage, to address the research objectives comprehensively.

The findings of this study are expected to contribute to the development of a technology-enhanced flipped classroom learning model aimed at enhancing creative problem-solving skills among undergraduate students. The proposed model is anticipated to be applicable to the instructional context of the Digital Photography Technology course, as well as other related subjects in higher education. Ultimately, this model aims to support the cultivation of a workforce equipped with competencies that align with industry demands and are adaptable to the rapid transformations of the modern world shown as Figure 1.

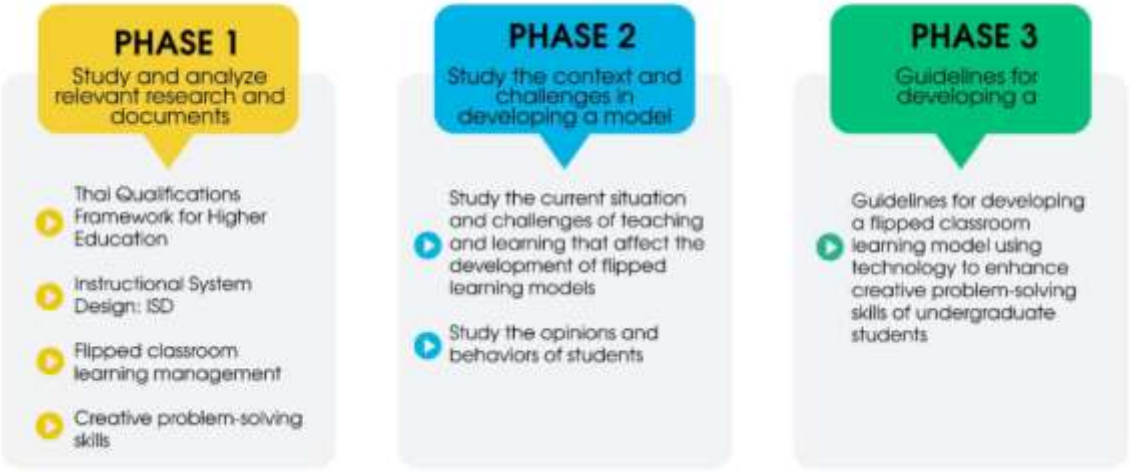

Figure 1: Phases of research process

IV. RESULTS

Phase 1: An Investigation into the current conditions and challenges of instructional practices among the university instructor's summary of findings

1. General background information

Among the five participants, the majority were male (3 individuals), accounting for 60%. Most respondents were aged between 41 and 50 years (two individuals, 60%). Regarding educational qualifications, 60% held doctoral degrees (two individuals). Two participants (60%) held academic positions. Most participants indicated that they had prior exposure to concepts related to creative problem-solving skills and the flipped classroom approach, particularly in the context of assessment and evaluation of learning outcomes (60%).

2. Information on the current conditions and challenges of instructional practices among university instructors

The results are presented in Table 1, as follows:

Table 1: A Comparison of the conditions and challenges in teaching and learning management among instructors

	Status	Problem
Input	**Course content dimension**	
	- Course content	- The instructional content outlined in the learning plan was extensive.
	Various instructional media were integrated into the course, including video clips, system demonstrations, instructional handouts, international textbooks, PowerPoint presentations, and information retrieval websites.	- Either instructional video materials were not provided or, when available, were too lengthy to be effectively applied to all topics covered in the course. - Case studies were presented based on each instructor's personal experiences.
	Student dimension	
	- Pre-instructional knowledge included foundational concepts and principles of photography, clarification of the course syllabus and instructional expectations, and fundamental understanding of image composition.	- Lacked fundamental skills in photographic principles - Lacked preparation prior to attending class Lacked a sense of responsibility - Demonstrated low motivation and enthusiasm for learning - Lacked teamwork skills, analytical thinking, problem-solving ability, and creativity in developing new systems
	Teaching faculty dimension	
	- The instructor demonstrated preparedness prior to teaching.	- There was no pre-assessment of students' knowledge prior to instruction.
	- There was evidence of instructional planning and course design.	- Few in-class learning activities were implemented. - Student participation in classroom activities was limited.
	- The instructional approach relied on lectures and case study presentations.	- Instructional materials varied and were individually developed by each instructor.

Table 1: (continued) A Comparison of the conditions and challenges in teaching and learning management among instructors

	Status	Problem
	Learning environment dimension	
	- The class followed a one-way lecture based format. - There were approximately 80 students per classroom.	- The space available for lighting setups in photography sessions was limited. - The number of students was relatively high.
	Learning activity design dimension	
Process	- Most in-class instruction relied heavily on lectures, with additional input from instructor-provided case studies and personal teaching experiences.	- There was insufficient instructional time allocated for providing consultation and feedback on students' group projects, which may have hindered effective supervision and formative assessment.
	- Group-based assignments were designed to reflect the characteristics of case studies previously presented during lectures.	- Some instructors do not include classroom activities. - Group work was often dominated by a few active participants, while meaningful consultation and collaboration among team members were lacking.
	- Out-of-class instructional activities primarily involved group projects and individual homework or practice exercises.	- Although students were required to undertake fieldwork and share the issues they encountered with their classmates, the activity did not elicit strong participation or meaningful interaction from their peers.

Table 1: (continued) A comparison of the conditions and challenges in teaching and learning management among instructors

	Status	Problem
	Assessment and evaluation	
Output	- The instructor assessed student performance through homework, assigned tasks, group work, in-class quizzes, midterm and final examinations, projects, and class attendance. - The evaluation was conducted using a norm-referenced grading system.	- This approach limited the ability to assess students' applied skills and did not reflect the full scope of their performance in real-world task execution.
	Outcome	
	- The students' scores were normally distributed.	- A lack of hands-on experience in system design hindered students' ability to conceptualize processes holistically. This gap negatively impacted their teamwork, innovation, and critical problem-solving skills, as reflected in their project assessment scores and performance during presentation-based inquiries.
Feedback	**Revise**	
	- Assessment data from the Office of the Registrar were reviewed during departmental meetings to guide instructional improvement and problem-solving initiatives.	

Phase 2: Study of students' opinions and learning behaviors. The findings can be summarized as follows

1. General information of the respondent's participant demographics and academic program distribution

The study involved a total sample of 215 undergraduate students, with the majority being female (141 participants or 65.58%) and the remainder male (74 participants or 34.42%). As shown in Figure 2, all participants were enrolled in the Bachelor of Industrial Education program. Additionally, they took the Digital Photography Technology course shown as Figure 3. The sample represented three academic disciplines; Architecture: 73 participants (33.95%), Interior Environmental Design: 67 participants (31.16%), Design Innovation and Technology: 75 participants (34.88%) This distribution reflects a diverse yet balanced representation across relevant design-focused disciplines, providing a meaningful context for evaluating the relevance and applicability of the course in supporting creative problem-solving skills within industrial education.

Figure 2: Digital technology curriculum management activities

Figure 3: An undergraduate student in instructional management in the digital photography technology course

2. Undergraduate students' opinion data regarding the current conditions and problems in instructional management in the digital photography technology course

Perceptions of the Current Instructional Conditions in the Digital Photography Technology Course An analysis of student perceptions regarding the current instructional conditions in the Digital Photography Technology course revealed that, overall, responses were rated at a high level ($\overline{x}$ = 4.20, SD = 0.73). When categorized by specific dimensions, the findings provide deeper insights into key aspects including instructional activity design, assessment evaluation, learning environment, content aspect, learner, and instructor, influencing the teaching and learning process as shown in Table 2.

Instructional activity design

In the area of instructional activity design, student perceptions were rated at a high level overall ($\bar{x}$ = 4.08, SD = 0.72). However, a closer examination of specific sub-factors revealed several critical issues; A lack of in-class activities that encourage students to practice thinking and problem-solving skills was identified as a major concern, receiving the highest rating ($\bar{x}$ = 4.41, SD = 0.62), indicating a high level of perceived deficiency. The absence of differentiated instruction that considers individual learning differences was also rated highly ($\bar{x}$ = 4.25, SD = 0.62), suggesting that teaching practices do not sufficiently address learner diversity. Additionally, instruction was found to lack a clear, step-by-step progression in teaching photographic techniques, which received a moderate rating ($\bar{x}$ = 3.87, SD = 0.77), indicating room for improvement in content sequencing and instructional clarity. These findings suggest that while instructional activities are generally viewed positively, there remain significant gaps in the design and delivery of activities that support deep learning, skill application, and learner-centered approaches.

Table 2: Perceptions of the current instructional conditions in the Digital Photography Technology course

Instructional management problems in the digital photography technology course	$\bar{x}$	SD	Level of problems
Instructional activity design dimension			
1. Lack of variety in teaching methods	3.81	0.79	Moderate
2. Instruction that does not consider individual differences	4.25	0.68	High
3. Failure to follow a sequential approach to teaching photography	3.87	0.77	Moderate
4. Lack of activities that engage students in practicing thinking and problem-solving skills during class sessions	4.41	0.62	High
Total	4.08	0.72	**High**
Assessment and evaluation dimension			
5. Emphasis on summative assessment through final examinations	4.70	0.51	Very high
6. Absence of pre-assessment to evaluate students' prior knowledge	4.02	0.92	High
7. Evaluation criteria that do not align with students' actual learning conditions	4.29	0.83	Very high
8. Lack of diverse assessment tools for measuring learning outcomes	4.36	0.57	High
Total	4.34	0.71	**High**
Learning environment dimension			
9. Excessive number of students per class group	4.02	0.71	High
10. Classroom conditions that are not conducive to group-based learning methods	3.83	0.76	Moderate
11. Outdated laboratory facilities that are inadequate for supporting current technologies	3.91	0.81	Moderate
Total	3.92	0.76	**High**

Table 2: (continued) Perceptions of the current instructional conditions in the Digital Photography Technology course

Instructional management problems in the digital photography technology course	$\bar{x}$	SD	Level of problems
Total	3.92	0.76	**High**
The content aspect dimension			
12. Course content does not align with the course description	4.49	0.70	High
13. Examples or case studies used in the course content lack variety	4.43	0.66	High
14. No new subject matter has been added to the course content	4.46	0.66	High
Total	4.46	0.67	**High**
Learner dimension			
15. Insufficient foundational knowledge	4.50	0.66	Very high
16. Lack of motivation to attend the Digital Photography Technology course	4.51	0.73	Very high
17. Lack of effort in completing exercises independently	4.32	0.83	High
18. Lack of enthusiasm in participating in classroom activities	4.04	0.82	High
19. Lack of responsibility in completing assigned tasks	3.99	0.79	Moderate
20. Lack of systematic thinking in problem-solving	4.38	0.69	High
Total	4.29	0.75	**High**
Instructor dimension			
21. Lack of communication regarding learning objectives for each class session	3.90	0.65	Moderate
22. Limited opportunities for students to ask questions during class	4.46	0.66	High
23. Insufficient time provided for student consultation outside of class	4.04	0.82	High
24. Lack of motivation-building strategies for students	4.05	0.88	High
25. Negative attitudes toward students who are unprepared for class	4.11	0.91	High
Total	4.11	0.78	**High**
In total	4.20	0.73	**High**

Assessment and evaluation

In the area of assessment and evaluation, the overall student perception was rated at a high ($\bar{x}$ = 4.34, SD = 0.71), indicating general satisfaction with the role of assessment in the instructional process. However, analysis of the subcomponents revealed notable concerns that reflect limitations in current assessment practices. The most critical issue identified was the heavy emphasis on end-of-semester examinations as the primary method of evaluating student learning outcomes, which received the highest mean score ($\bar{x}$ = 4.70, SD = 0.51). This suggests that summative assessment dominates the instructional process, potentially at the expense of formative and performance-based assessments that foster continuous learning and skill application. Another key finding was the limited use of diverse assessment tools, with a mean score of ($\bar{x}$ = 3.36, SD = 0.57). This indicates a lack of variety in evaluation methods such as project-based assessments, peer evaluations, presentations, and reflective tasks which are essential for capturing complex learning outcomes, particularly in creative and applied fields like digital photography. Additionally, the misalignment between assessment criteria and the real-life contexts of learners was also highlighted ($\bar{x}$ = 4.29, SD = 0.83). This points to a disconnect between theoretical expectations and students' practical learning environments, reducing the relevance and authenticity of assessment results. Collectively, these findings underscore the need for a more balanced and contextualized assessment approach, one that incorporates both summative and formative methods, utilizes varied tools, and aligns evaluation criteria with authentic learning experiences to effectively support creative problem-solving and deeper learning outcomes.

Learning environment

The overall perception of students regarding the learning environment was rated at a high level ($\bar{x}$ = 3.62, SD = 0.58). However, when examining the subcomponents in detail, several specific issues were identified. The most prominent concern was the excessive number of students per class, which was rated at a high level ($\bar{x}$ = 4.02, SD = 0.71). Large class sizes may impede personalized instruction and reduce opportunities for active engagement in learning activities. Additionally, the outdated laboratory facilities were rated at a moderate level ($\bar{x}$ = 3.91, SD = 0.81). These facilities were perceived as insufficient to support the use of modern technologies necessary for inquiry-based learning and digital experimentation. Moreover, the physical layout of the classroom was considered unsupportive of collaborative or group-based learning methods, also receiving a moderate rating ($\bar{x}$ = 3.83, SD = 0.76). This suggests that current classroom configurations may not be conducive to interactive, student-centered instructional strategies.

Course content, learners, and instructors

In the area of course content, student perceptions were rated at a high level overall ($\bar{x}$ = 4.46, SD = 0.67). However, further analysis of subcomponents revealed several key issues. The highest concern was the misalignment between the actual course content and the course description ($\bar{x}$ = 4.49, SD= 0.70). In addition, students noted that there was no integration of newly updated content into the course ($\bar{x}$ = 4.46, SD = 0.66), reflecting a lack of curriculum renewal. Furthermore, the examples and case studies used in the course were reported to be limited in variety ($\bar{x}$ = 4.43, SD = 0.66), indicating a need for more diverse instructional materials.

In the area of learners, perceptions were also at a high level ($\bar{x}$ = 4.29, SD = 0.75). Among the subcomponents, the most prominent issue was a lack of motivation among students to attend the Digital Photography Technology course ($\bar{x}$ = 4.51, SD = 0.73). This was followed by students reporting insufficient foundational knowledge ($\bar{x}$ = 4.50, SD = 0.66), and a lack of structured thinking processes in solving problems ($\bar{x}$ = 4.38, SD = 0.69). These findings suggest that cognitive and affective readiness among students may be a barrier to effective learning.

Regarding instructors, the overall perception was again at a high level ($\bar{x}$ = 4.11, SD = 0.78). However, several issues were identified. The most critical thing was that instructors provided limited opportunities for students to ask questions during class sessions ($\bar{x}$ = 4.46, SD = 0.66). Moreover, instructors were perceived to hold negative attitudes toward students who were not well-prepared ($\bar{x}$= 4.11, SD = 0.91), and to lack strategies for motivating learners ($\bar{x}$ = 4.05, SD = 0.88).

Collectively, these findings highlight the need for pedagogical reforms that promote curriculum relevance, student engagement, foundational knowledge development, and inclusive teaching attitudes. Addressing these issues is essential for creating a more responsive and effective instructional environment, particularly in practice-based courses such as digital photography.

3. Learning behavior data of undergraduate students in the Digital Photography Technology course

An analysis of student learning behaviors in the Digital Photography Technology course revealed that the overall level of learning behavior among undergraduate students was rated high ($\bar{X}$ = 4.43, SD = 0.69). When categorized by specific domains, pre-class preparation, critical thinking and problem solving, and collaboration, the findings as shown in Table 3 are as follows:

Pre-class preparation

Students demonstrated a high level of readiness before attending class ($\bar{x}$ = 4.47, SD = 0.66). Within this domain, the highest-rated subcomponent was that students set clear goals to succeed in the course ($\bar{x}$ = 4.73, SD = 0.49), followed by their engagement in pre-lesson study prior to class sessions ($\bar{x}$ = 4.20, SD = 0.89), both rated at a high level.

Critical thinking and problem-solving

This domain was also rated highly ($\bar{x}$ = 4.44, SD = 0.72). Specifically, students reported a strong ability to summarize the process of problem analysis ($\bar{x}$ = 4.77, SD = 0.52), to synthesize knowledge or principles from multiple examples ($\bar{x}$ = 4.69, SD = 0.56), and to formulate guiding questions or issues to address problems ($\bar{x}$ = 4.64, SD = 0.65). Each subcomponent was rated at the highest level, indicating strong engagement with analytical and reflective thinking.

Collaboration

Student behavior in collaborative learning was also rated at a high level ($\bar{x}$ = 4.39, SD = 0.69). Subcomponent analysis showed that students actively participated in classroom activities ($\bar{x}$ = 4.76, SD = 0.43), respected differing viewpoints during group work ($\bar{x}$ = 4.69, SD = 0.59), and were able to respond to questions or explain concepts to peers who experienced difficulties ($\bar{x}$ = 4.66, SD = 0.52). All subcomponents were rated at the highest level, highlighting strong interpersonal engagement and peer support.

Table 3: Student learning behaviors in the Digital Photography Technology course

Learning behaviors in the Digital Photography Technology course	$\bar{x}$	SD	Level of behavior
Preparation before class			
1. Learners set goals to achieve success in their studies	4.73	0.49	Very high
2. Learners review lessons in advance before attending class.	4.20	0.89	High
Total	**4.47**	**0.66**	**High**
Critical thinking and problem-solving			
3. Learners are able to synthesize knowledge or principles from multiple examples	4.69	0.56	Very high
4. Learners can apply knowledge or principles to solve specific problems	4.11	0.91	High
5. Learners can clearly elaborate on their conclusions	4.60	0.62	Very high
6. Learners can evaluate and analyze the given problems	4.50	0.70	High
7. Learners can summarize the process of problem analysis	4.77	0.52	Very high
8. Learners can summarize the process of problem analysis	4.11	0.91	High
9. Learners are able to identify key issues as a basis for problem-solving	4.64	0.65	Very high
10. Learners can connect information and conclusions to the problems encountered	4.11	0.91	High
Total	4.44	0.72	**High**
Collaboration			
11. Learners actively participate in classroom activities.	4.76	0.43	Very high
12. Learners engage in extracurricular learning activities.	4.11	0.91	High
13. Learners accept differing opinions during group work	4.69	0.59	Very high
14. Learners seek clarification from peers who are more knowledgeable	4.05	0.79	High
15. Learners are able to answer questions or explain lesson content to peers with uncertainties	4.66	0.52	Very high
16. Learners exchange knowledge with peers outside the classroom	4.02	0.81	High
17. Learners take responsibility for their assigned tasks in group work	4.49	0.73	High
18. Learners share responsibility for the tasks assigned within the group	4.35	0.78	High
Total	4.39	0.69	**High**
In total	4.43	0.69	**High**

These results suggest that students in the Digital Photography Technology course exhibit a well-rounded set of learning behaviors, particularly in the areas of goal setting, critical thinking, and teamwork. Such behaviors are essential for developing higher-order cognitive skills and for fostering active, student-centered learning in applied disciplines. To address these challenges, the study proposes a development model, shown as Figure 4, which

integrates in-class activities centered on creation and understanding with out-of-class resources and interactive opportunities. This model incorporates feedback loops grounded in the IPO framework and applies Paul and Elder's elements of thought to deepen cognitive engagement. When implemented within a strategically designed instructional system, such as a technology-enhanced flipped classroom, this approach fosters creativity, enhances learner engagement, and facilitates effective knowledge transfer, aligning with findings from the researches by Bergmann and Sams, (2012, pp. 35-50) and Tucker (2020, pp. 7-8).

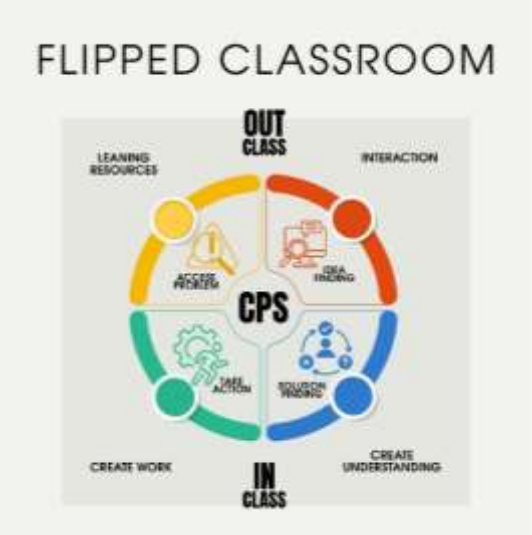

Figure 4: Model development

V. CONCLUSION AND DISCUSSION

In conclusion, the findings from Phase 1 of the study revealed key instructional challenges that influenced the development of a flipped classroom model designed to foster creative problem-solving among undergraduate students. These findings are organized into three major dimensions based on the Input-Process-Output (IPO) framework: First, input factors consist of course content, students, instructors, learning environment, and process factor. Although instructors employed a variety of instructional materials, the content was often overloaded and not effectively applicable across all topics. Moreover, examples drawn from instructors' personal experiences were found to lack relevance to students' contexts. According to Bergmann and Sams (2012, pp. 35-50). The use of technology such as instructional videos can help students grasp content better and allow for continuous refinement based on learner feedback. Students were found to possess a moderate level of foundational knowledge in photography concepts and principles; however, they lacked learning readiness, responsibility, analytical thinking, creativity, collaboration, and confidence in expressing ideas. Most instructors relied on lectures and case examples, with limited implementation of diverse hands-on activities. This limitation was partly attributed to large class sizes and the need to cover a wide range of content. The classroom setting, which typically consisted of approximately 80 students per session, contributed to a unidirectional (lecture-based) instructional format. The physical layout restricted instructors' ability to move freely and monitor student work effectively during in-class activities. Instructional practices in the classroom were primarily lecture-based, focusing on examples and instructor narratives in order to cover planned content. Although some instructors attempted to integrate group activities, student participation was limited due to a lack of confidence in sharing opinions. Out-of-class

learning was often structured around group projects, with students self-organizing into teams and working primarily at the end of sessions. Time constraints limited the opportunity for consultation and guidance, which hindered the effectiveness of core project components such as system design and testing. Chan et al. (2015, pp. 96-106) emphasized the value of smartphones in promoting student expression, peer interaction, and the pursuit of new knowledge through social and academic motivation. Similarly, Chuang (2017, pp. 688-693) found that smartphones can facilitate high-level collaborative learning when used effectively. Second, output factors include assessment and evaluation and Learning Outcomes. Assessment practices followed the lesson plan and included quizzes, midterm and final exams, and attendance records, using a norm-referenced grading system. Group projects were graded solely on final presentations, with no use of rubric. This approach limits the ability to evaluate students' practical competencies. Although the average student's performance appeared acceptable, critical skill gaps remained-particularly in system design, problem analysis, creativity, and teamwork. Panadero and Jonsson (2013, pp. 129-144) highlighted that using rubrics for formative assessment can reduce learner anxiety, provide clearer feedback, and enhance self-improvement and transparency in evaluation processes, thereby better supporting student performance in applied contexts. In phase 2, the analysis revealed that instructional design lacked a variety of examples or case studies and failed to incorporate updated content relevant to contemporary contexts. This shortcoming may be attributed to lecture-based teaching methods in large classroom settings, where instruction primarily relies on textbooks and instructors' personal experiences. According to Chang and Yu (2015, pp. 38-43), a learning environment that fosters creativity is positively correlated with innovative performance. Therefore, creating instructional settings that promote students' creative expression is essential. Students demonstrated low motivation and limited communication skills, particularly in out-of-class activities such as those in software engineering courses. This reflects a deficiency in essential 21st-century digital competencies. Organizations like ISTE (2016, online) emphasize the use of information and communication technologies (ICT) to support innovation and collaboration. Similarly, Phuapan et al. (2015, pp. 24-31) advocate for the integration of ICT to enhance learning, communication, and cooperation in higher education environments. Instructors were reported to provide insufficient motivation during lessons and limited opportunities for student questioning. Dick and Carey (2015, pp. 218-243) highlighted the significance of motivation using, Keller (1987, pp. 2-10) ARCS model, which comprises Attention, Relevance, Confidence, and Satisfaction all essential elements in enhancing learning performance. The instructional activities in class were neither diverse nor sufficiently effective in promoting analytical thinking or problem-solving skills. Bergmann and Sams (2012, pp. 35-50) proposed the flipped classroom model to stimulate students through inquiry-based learning and project work. Likewise, Flaherty and Phillips (2015, pp. 85-95) found that flipped learning promotes deeper learning, critical thinking, and sustained student engagement. The evaluation process relied heavily on final examinations, with limited use of formative assessment. Morrison et al. (2001, pp. 79-83) recommend learner analysis as a prerequisite to understanding prior knowledge. Gerlach and Ely (1980, pp. 200-238) also emphasized the importance of assessing entering behaviors as a foundation for designing effective instructional interventions. Large class sizes were found to inhibit group-based learning. Gerlach and Ely (1980, pp. 200-238) suggested that learner grouping should be determined by objectives, content, and learning methods. Giannakos et al. (2016, pp. 978-988) recommended the use of video-based learning ecosystems to support active learning in large cohorts, providing effective knowledge transmission and participation. Students demonstrated low levels of pre-class study behavior. Bergmann and Sams (2012, pp. 35-50) emphasized that preparation prior to class enhances content understanding through review, inquiry, and practice. Yousef et al. (2014, pp. 9-20) further noted that technologies such as MOOCs and

educational videos can effectively support both formal and informal learning. Students struggled to apply knowledge in real-life contexts, limiting the development of innovation-related skills. Chang et al. (2014, pp. 107-123) found that environments supporting creativity positively influence innovation performance. Additionally, cloud-based mobile learning (m-learning) was identified as a motivational tool that can enhance creative thinking. Students were unable to clearly elaborate or extend their conclusions. Kong (2014, pp. 160-173), in his study on digital classroom learning, found that well-designed instruction enhances information literacy and deep critical thinking in students. Students showed reluctance to communicate or ask questions, which impeded their teamwork capabilities. Liao et al. (2015, pp. 105-122) discovered that social networking platforms can foster enjoyment, engagement, and positive learner attitudes. These tools also promote collaborative learning and long-term motivation to participate actively.

In discussion, after reviewing the research, students demonstrated high levels of learning behaviors across all domains. Pre-class preparation had the highest mean ($\bar{x}$ = 4.47, SD = 0.66), indicating strong responsibility and readiness. Critical thinking and problem solving ($\bar{x}$ = 4.44, SD = 0.72) showed their ability to analyze and address issues effectively. Collaboration ($\bar{x}$ = 4.39, SD = 0.69) reflected good teamwork and communication skills. Overall, the results suggest students are well-equipped with key 21st-century learning skills. The study revealed several significant constraints within the instructional environment, particularly in the input and process dimensions as framed by the Input-Process-Output (IPO) model. These constraints include overloaded course content, lecture-centric teaching methods, large class sizes, and outdated laboratory facilities, consistent with observations by (UNESCO, 2015, pp. 113-114). Although the IPO framework emphasizes active reasoning and student engagement, instructors faced limited time for meaningful dialogic interaction. This structural limitation negatively impacted the development of students' problem-solving skills, as also noted by Mulder (2017, pp. 739-742). From the students' perspective, creative problem-solving abilities were rated highly ($\bar{x}$ = 4.44), suggesting a strong self-perceived competence. However, notable deficiencies were identified in terms of instructional variety and misalignment between assessment practices and intended learning outcomes. These discrepancies reflect a divergence from the intellectual standards of clarity, logic, and significance outlined by Paul and Elder (2006, pp. 19-22).

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