Asian Journal of Contemporary Education
ISSN(e): 2617-1252
DOI: 10.55493/5052.v9i2.5529
Vol. 9, No. 2, 184-198.

Enhancing innovative thinking of digital technology teacher students by using project-based learning: Case of Nakhon Sawan Rajabhat University in Thailand

Siribhorn Buranahirun[1]
Wudhijaya Philuek[2+]

[1,2]Faculty of Education, Nakhon Sawan Rajabhat University, Thailand.
[1]Email: siriporn.p@nsru.ac.th
[2]Email: wudhijaya@nsru.ac.th

(+ Corresponding author)

Article History
Received: 28 May 2025
Revised: 30 July 2025
Accepted: 7 August 2025
Published: 11 August 2025

Keywords
Innovative thinking
Nakhon Sawan Rajabhat University
Project-based learning
Teacher students.

ABSTRACT

This research aimed to study students' innovative thinking by using Project-Based Learning. The quasi-experimental one-group pretest/posttest design was implemented for the target group, which consisted of 29 third-year Digital Technology teacher students who were enrolled in the second semester of the academic year 2023. Research instruments included learning management plans based on Project-Based Learning, an innovative thinking assessment form, and a project assessment form. The statistics such as percentage, mean, standard deviation, t-test, and Pearson's correlation coefficient were used for data analysis. The result showed 1) there was posttest score of all observed variables in innovative thinking higher than pretest, 2) there was different between pretest and posttest of latent variables in innovative thinking a significance level of 0.01 ($p<.01$), 3) the score of project works were between 77-88 points, 4) the correlation coefficients between observed variables with statistically significant values different from zero ($p<.01$) were 42 pairs and from zero ($p<.05$) were 21 pairs, and 5) the correlation coefficients between latent variables with statistically significant values different from zero ($p<.01$) were 6 pairs. The results show that Project-Based Learning can be used to promote innovative thinking in digital technology teacher-students, which may be applied to other teacher-students in the future.

Contribution/ Originality: This research is a study of the implementation of the Project-Based Learning approach to promote innovative thinking among Digital Technology for Education teacher students, which encourages them to develop innovative projects that are one of the content areas and capabilities they will need to use in teaching students in the future.

1. INTRODUCTION

The rapid growth in technology and markets is pushing companies to increase their innovation efforts and speed up product launches. Despite this, many innovations often result in disappointment due to high uncertainty, risk, and disruptive trends in today's business environment. Successful innovation requires good execution, emphasizing the importance of focusing on projects as part of the innovation process. By merging innovation and project management principles, companies can better focus on critical issues in innovative and disruptive environments, leading to more effective execution. Overall, the paper suggests that companies can achieve innovation success by integrating project management practices with innovation efforts, ultimately improving their ability to bring ideas to market successfully (Shenhar et al., 2020). The 21st century emphasizes innovation in various fields like science, education, and culture, focusing on creative transformation and world improvement (Anufrieva, Ivanova, Pereverzeva, Cheshenko, & Ovsyannikova, 2020) and to develop young innovators for the 21st-century workforce, a comprehensive set of skills and competencies is essential. Key competencies include critical thinking, creativity, problem-solving, and effective communication, which are vital for navigating complex challenges and fostering innovation (Cavichioli, Conceição, & Costa, 2024; Ramamonjisoa, 2024; Todorova, 2024). Additionally, adaptive thinking, social intelligence, and intercultural competence are crucial for collaboration in diverse environments (Muldagaliyeva, Dosmagambetova, & Kulzhanbekova, 2023). The integration of digital literacy and algorithmic thinking prepares students for a technology-driven landscape, while design thinking encourages innovative solutions to real-world problems (Muldagaliyeva et al., 2023; Ramamonjisoa, 2024). Furthermore, fostering a growth mindset and lifelong learning capabilities ensures that individuals remain adaptable and responsive to rapid changes in society and the economy (Brooks-Young, 2010; Ramamonjisoa, 2024). Collectively, these competencies equip young innovators to thrive in an interconnected and dynamic future. Innovative thinking in teacher education involves fostering creativity and unique approaches to teaching and learning, utilizing modern educational technologies, and implementing divergent thinking strategies to enhance students' innovative abilities. Some studies emphasize the importance of developing creative thinking through courses designed with innovative technologies (Wang & Burdina, 2024) and recognizing the role of teachers in cultivating creativity and innovative thinking among students (Fasel Mkawin, 2022). Innovative teaching methods, such as blended learning and ubiquitous learning, are highlighted as effective ways to improve education and empower individuals for self-reliance. Additionally, integrating a design thinking mindset in content delivery can enhance teachers' ability to innovate in delivering educational material, ultimately benefiting student engagement and performance (Gopinathan, Kaur, Ramasamy, & Raman, 2022). By incorporating these innovative approaches, teacher education students can develop the necessary skills to adapt to the evolving educational landscape and foster a culture of creativity and innovation in the classroom.

2. LITERATURE REVIEW

In this study, the author presents a literature review consisting of Project-Based Learning (PjBL) and innovative thinking.

2.1. Project-Based Learning (PjBL)

PjBL is an educational approach that emphasizes learning through engaging in real-world projects. It is important for both teachers and students because it transforms the traditional classroom dynamic, fosters deeper learning, and prepares students for future challenges.

For Students, PjBL makes learning more relevant by connecting to real-world problems. Students are more motivated when they see the purpose behind their work. According to Thomas (2000), PjBL increases student engagement by allowing them to explore topics that are meaningful and relevant to their lives. PjBL requires students to analyze information, think critically, and solve complex problems, which are essential skills for the 21st century. Hmelo-Silver (2004) found that PjBL enhances students' problem-solving abilities and helps them develop higher-order thinking skills and often involves teamwork, helping students develop collaboration and communication skills. Bell (2010) highlights that PjBL fosters social skills and teamwork, which are critical for success in both academic and professional settings. Students take responsibility for their learning, fostering independence and self-directed learning skills. Larmer, Mergendoller, and Boss (2015) emphasize that PjBL empowers students to take ownership of their projects, making them active participants in their education. PjBL allows students to apply theoretical knowledge to real-world situations, deepening their understanding and retention of concepts. Barron and Darling-Hammond (2008) found that students in PjBL environments perform better in applying knowledge to new contexts compared to traditional learning methods. PjBL mirrors the collaborative, problem-solving nature of modern workplaces, preparing students for future careers. The Partnership for 21st Century Skills (2009) identifies PjBL as a key strategy for developing skills like critical thinking, collaboration, and creativity, which are essential for workforce readiness. In addition, PjBL fosters a deeper understanding of content, builds essential life skills, and prepares students for future challenges.

For teachers, PjBL shifts the teacher's role from a lecturer to a facilitator, allowing them to guide and support students rather than simply deliver content. According to Blumenfeld et al. (1991), PjBL encourages teachers to act as facilitators, fostering a more student-centered learning environment. Teachers gain insights into students' strengths, interests, and learning styles as they observe them. Darling-Hammond et al. (2008) note that PjBL allows teachers to better understand individual student needs and tailor instruction accordingly. Implementing PjBL encourages teachers to innovate, experiment with new teaching strategies, and continuously improve their practice. Ertmer and Simons (2006) highlight that PjBL challenges teachers to adopt new roles and strategies, promoting professional development. Teachers can connect curriculum standards to real-world issues, making their teaching more meaningful and impactful. Krajcik and Shin (2014) emphasize that PjBL helps teachers make learning more relevant by linking it to real-world challenges. PjBL provides opportunities for authentic assessment, allowing teachers to evaluate students' understanding through their project outcomes rather than just tests. Barron and Darling-Hammond (2008) suggest that PjBL enables teachers to assess students' skills and knowledge in a more holistic and authentic way. To sum up, PjBL encourages innovation, collaboration, and a more dynamic teaching approach, ultimately enhancing the learning experience for both teachers and students.

Effective assessment of PjBL, effective assessment of student learning outcomes in PjBL environments can be achieved through a combination of innovative and traditional assessment strategies. Research indicates that employing a mix of summative, formative, and diagnostic assessments enhances the evaluation process, allowing educators to monitor student progress throughout the project lifecycle (Moon, Brighton, & Hock, 2022). Additionally, project-based assessments, such as portfolios and peer assessments, foster critical thinking and engagement, providing a holistic view of student capabilities (Devaki, 2024; Moon et al., 2022). The integration of rubrics aligned with Bloom's taxonomy further supports structured feedback and cognitive development, ensuring that assessments are both comprehensive and reflective of learning objectives (Ayyanathan, 2022). Overall, these multifaceted approaches not only improve learning outcomes but also motivate students by connecting assessments to real-world applications (Caniago, 2024; Moon et al., 2022).

2.2. Innovative Thinking

2.2.1. Innovation Skills

Innovative skills training for teachers has been shown to significantly enhance student outcomes and academic performance. Research indicates that innovative teaching methods, such as experiential learning and technology integration, foster critical thinking and creativity among students, which are essential for success in modern educational contexts (Dighliya, 2025). Additionally, training programs focused on digital teaching materials have demonstrated improvements in teacher competencies, leading to better student learning performance, as evidenced by pretest and post-test results showing an increase in average scores (Kadarisman, Asnah, & Suryo, 2022).

Furthermore, studies reveal that creativity training for teachers positively impacts students' academic achievement, highlighting the importance of moving away from traditional, passive learning methods (Baradaran, Khosravipour, Rafe, Moosavi, & Roozbahani, 2015). Finally, an online program designed to enhance teachers' innovation skills resulted in statistically significant improvements in both teacher performance and student innovation skills, confirming the effectiveness of such training initiatives (Niruttimatee & Sanrattana, 2022). Overall, these findings underscore the critical role of teacher training in driving student success.

2.2.2. Innovative Thinking Enhances Performance

Innovative thinking significantly enhances organizational performance and competitiveness by fostering a culture that embraces change and technological advancement. Research indicates that organizations with strong innovation capabilities can mediate improvements in performance through effective organizational innovation, particularly in manufacturing contexts (Sina Setyadi & Woro Hastuti, 2024). Furthermore, companies that integrate advanced technologies and innovative management practices tend to achieve higher productivity and operational efficiency, underscoring the importance of proactive innovation strategies (Vittorio, Rajuddin, & Dewi, 2024). The ability to navigate risks and support from leadership are critical in implementing these innovations, which can lead to sustainable competitive advantages. Innovative thinking significantly enhances organizational performance and competitiveness by integrating new strategies, improving operations, and refining marketing approaches. Organizations that embrace innovation, supported by leadership and a conducive culture, can achieve sustainable competitive advantages in dynamic markets (Delhi, Sana, Angelina Bisty, & Husain, 2024). Additionally, adopting ambidextrous innovation strategies allows firms to balance the exploration of new capabilities with the exploitation of existing resources, thereby maintaining their competitive edge in dynamic environments (Ioniţă, 2022). Overall, a commitment to innovation not only drives corporate performance but also enhances market reputation and profitability (Manji & Laghari, 2022). Innovative thinking refers to the process of generating novel and original ideas to solve problems, which is crucial for success in various domains such as education, business, and technology. It encompasses analytical, logical, creative, critical, and intuitive thinking, among others, as highlighted in the research papers (Ritambhara & Singh, 2023; Vyacheslavovna, 2022). Furthermore, innovative thinking plays a significant role in the teaching of disciplines like e-commerce, aiming to optimize teaching structures and enhance student learning outcomes in the rapidly evolving digital era (Li, 2022).

To enhance and develop innovative thinking, various strategies can be employed based on the insights from the research papers. Firstly, educational programs should focus on cultivating innovative capacity through enhanced entrepreneurial education, skills development, and technology exchange (Mugione & Penaluna, 2018). Teachers can play a crucial role by motivating students to engage in better learning practices and fostering maximum innovation in thinking (Wang & Zhu, 2015). Additionally, mechanisms that trigger innovative mental activities, such as analytical, logical, imaginative, and critical thinking, should be considered within innovation-oriented companies to promote innovative thinking among employees (Sokerina, 2021). Moreover, incorporating innovative heuristics and tools, enhancing observation, using analogies, and broadening perspectives can break habitual thought patterns and stimulate originality (Ness, 2015). Lastly, implementing disruptive educational approaches that focus on enhancing thinking skills and fostering innovation can significantly contribute to developing innovative thinking among learners (Wisetsat & Nuangchalerm, 2019).

2.2.3. Project-Based Learning (PjBL) and Innovation Thinking

PjBL has emerged as a transformative educational approach that fosters innovation and enhances practical skills across various educational contexts. Research indicates that PjBL effectively cultivates essential competencies such as creativity, teamwork, and problem-solving, particularly in technical fields like engineering and information technology (Mahtani, Guerrero, & Decroix, 2024; Rasulova, 2024). For instance, a hybrid learning model integrating PjBL with digital tools has significantly improved design-thinking skills among IT students, demonstrating its relevance in the digital era (Lubna, Suhirman, & Prayogi, 2024).

Furthermore, studies show that PjBL not only boosts academic performance but also enhances critical thinking and student engagement, with reported increases of 25% in problem-solving skills and 30% in critical thinking abilities (Mahtani et al., 2024). Similar to Widodo (2024), who claimed that PjBL enhances innovation by fostering creative thinking, problem-solving skills, and collaboration among students. The study indicates that PjBL significantly improves students' creative output and academic performance, highlighting its effectiveness in cultivating innovative capabilities. However, challenges such as resource limitations and the need for teacher training persist, emphasizing the necessity for supportive measures to optimize PjBL implementation (Nugraha & Mardiyati, 2024). Overall, PjBL represents a vital strategy for fostering innovation and preparing students for real-world challenges.

3. METHODOLOGY

This research utilized a quasi-experimental research design method. The sample consisted of 29 third-year Digital Technology teacher students who were enrolled in the STEM Education course during the second semester of the academic year 2023 at Nakhon Sawan Rajabhat University, Thailand. The research tools included 1) lesson plans, 2) an Innovation Thinking self-evaluation form, and 3) a project evaluation form.

The Innovation Thinking self-evaluation form, based on a modified tool developed by Barak et al. (2020), for assessing innovative thinking in engineering students demonstrates significant advancements over existing assessments by establishing both validity and reliability through a self-report mechanism tailored to individual differences in innovative thinking. Unlike traditional methods, which often focus on rote knowledge transfer, this tool emphasizes personal reflection and self-assessment, aligning with contemporary educational needs for creativity and problem-solving skills in engineering contexts (Adilmurdin & Laikov, 2023). Comparatively, other assessments, such as the Design Thinking Creativity Test (DTCT), also aim to capture applied creativity but primarily through case-based scenarios, which may not fully encompass the individual cognitive processes involved in innovation (Hawthorne et al., 2016). Furthermore, the tool's development process involved rigorous quantitative analyses, ensuring a robust framework that can effectively measure distinct dimensions of innovative thinking, as evidenced by the five-factor solution identified in related studies (Sukkeewan, Songkram, & Nasongkhla, 2024). Thus, Barak et al. (2020) 's tool represents a more nuanced approach to evaluating innovative thinking, addressing gaps in current assessment methodologies.

The research data collection was conducted by informing students of the research objectives and the teaching procedures over a total of 8 weeks and 32 periods. In the teaching and learning activities, the Project-Based Learning approach was employed. The researcher collected data prior to the study by having students complete a self-evaluation of Innovative Thinking and collected data after the 8-week period. The students' projects were evaluated and scored using a rubric. The test results were analyzed by calculating the mean, standard deviation, conducting an independent t-test, and performing Pearson's correlation analysis.

4. RESULTS

From the research on the topic of enhancing innovative thinking of digital technology teacher students by using project-based learning: Case of Nakhon Sawan Rajabhat University in Thailand, the researcher would like to summarize the research results as follows.

Table 1. Pre- and post-innovation thinking self-evaluation.

Innovation thinking factors	Pre-		Post-	
	Mean	S.D.	Mean	S.D.
Observing				
Obs1: While learning, I think of new ideas that come through observing the world.	3.17	0.47	4.03	0.68
Obs2: New ideas often come to me when observing how other learners interact and do things.	3.45	0.68	4.03	0.82
Obs3: I regularly observe things around me to get new ideas.	3.34	0.77	4.03	0.91
Total observing	*3.32*	*0.42*	*4.03*	*0.61*
Questioning				
Que1: While learning, I often ask questions that challenge the status quo.	3.28	0.70	3.90	0.90

Innovation thinking factors	Pre-		Post-	
	Mean	S.D.	Mean	S.D.
Que2: I regularly ask questions that challenge other learners' assumptions.	3.45	0.63	4.10	0.61
Que3: Other learners are challenged by my questions.	3.31	0.89	3.86	0.69
Total questioning	*3.34*	*0.56*	*3.97*	*0.58*
Networking				
Net1, I have a network with which I interact to get new ideas.	3.31	0.96	4.00	0.84
Net2, I have a network of learners whom I trust to bring new perspectives and refine new ideas.	3.51	0.95	4.13	1.09
Net3, I initiate meetings with other learners to spark new ideas.	3.48	0.74	4.00	1.00
Net4, I participate in diverse professional and/or academic forums.	3.41	0.73	4.03	0.82
Total networking	*3.43*	*.60*	*4.04*	*0.73*
Experimenting				
Exp1, When learning, I actively search for new ideas through experimenting.	3.17	0.76	4.21	0.97
Exp2, I experiment to understand how things work and create new ways of doing things.	3.27	0.96	4.24	0.87
Exp3, I actively search for new ideas through experimenting.	3.23	1.02	4.10	0.93
Total experimenting	*3.23*	*0.80*	*4.18*	*0.85*

Table 1 demonstrates that the self-assessment scores on Innovative Thinking in each aspect showed that overall, the post-learning scores were higher than the pre-learning scores. In the aspect of Experimenting, the post-learning scores were the highest (Mean = 4.18, S.D. = 0.85), followed by Networking (Mean = 4.04, S.D. = 0.73), Observing (Mean = 4.03, S.D. = 0.61), and Questioning (Mean = 3.97, S.D. = 0.58), respectively. In terms of sub-items, it was found that the observed variable Exp2, I experiment to understand how things work and create new ways of doing things had the highest score (Mean = 4.24, S.D. = 0.87), and the observed variable Que1, while learning, I often ask questions that challenge the status quo had the lowest score (Mean = 3.90, S.D. = 0.90).

Table 2. T-test of innovation thinking.

Factors	Test	Mean	S.D.	N	t	df	Sig. (2-tailed)
Observing	Pre-test	3.32	0.42	29	-6.171	28	0.000
	Post-test	4.03	0.61				
Questioning	Pre-test	3.34	0.56	29	-5.386	28	0.000
	Post-test	3.97	0.58				
Networking	Pre-test	3.43	0.60	29	-5.601	28	0.000
	Post-test	4.04	0.73				
Experimenting	Pre-test	3.23	0.80	29	-5.505	28	0.000
	Post-test	4.18	0.85				

Table 2 shows the results of the dependent t-test found that the four variables of innovative thinking, namely Observing, Questioning, Networking, and Experimenting, had significantly higher mean scores after learning than before learning at the 0.05 level, while all four variables were less than the 0.01 level.

Table 3. Score of project works.

Group	Name of project	Score from 100 points
Group 1	Development of real-time automatic vehicle noise detection	85
Group 2	Development of a motorcycle license plate recognition system	80
Group 3	Development of panic and nervousness detection devices with a DIY smart watch for student learning	86
Group 4	Development of an aeroponics system for growing orchids in school smart	73

Group	Name of project	Score from 100 points
	greenhouses.	
Group 5	Development of a real-time dust level detection device in the classroom to study classroom cleanliness	84
Group 6	Development of a carbon dioxide level detection device	85
Group 7	Development of school student pick-up and drop-off applications	72
Group 8	Using phonological analysis to evaluate the Thai consonant pronunciation of early childhood students	88

Table 3 shows the scores of the group work that students developed, totaling 8 projects, consisting of Group 1 Development of Real-Time Automatic Vehicle Noise Detection, Group 2 Development of Motorcycle License Plate Recognition System, Group 3 Development of Panic and Nervousness Detection Devices with DIY Smart Watch for Student Learning, Group 4 Development of Aeroponics System for Growing Orchids in School Smart Greenhouses, Group 5 Development of a Real-Time Dust Level Detection Device in the Classroom to Study Classroom Cleanliness, Group 6 Development of Carbon Dioxide Level Detection Device, Group 7 Development of School Student Pick-Up and Drop-Off Applications, and Group 8 Using Phonological Analysis to Evaluate Thai Consonant Pronunciation of Early Childhood Students. The group with the highest scores was Group 8. The work developed by the students was presented at the 6th National Conference on Teacher Education at Chiang Mai Rajabhat University in 2024 and received the Best Paper award. And from Figures 1 to 4 showing some project and screen pictures.

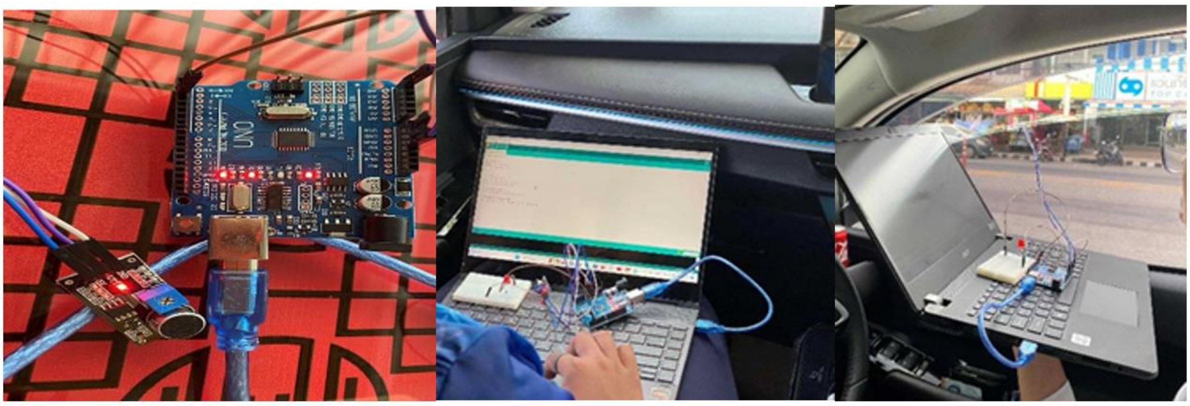

Figure 1. Picture of group one's work: Development of real-time automatic vehicle noise detection.

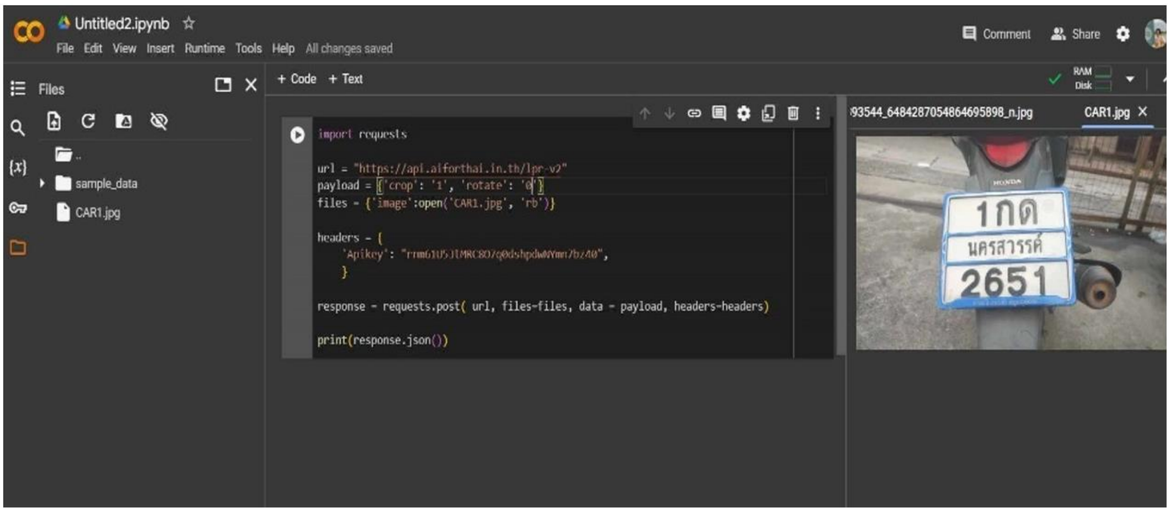

Figure 2. Picture of group two's work: Development of a motorcycle license plate recognition system.

Figure 3. Picture of group three's work: Development of panic and nervousness detection devices with a DIY smart watch for student learning.

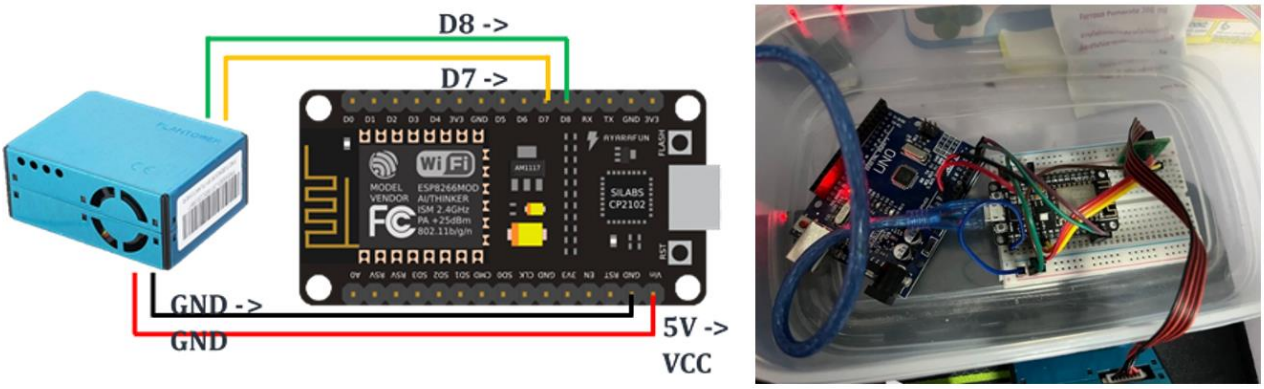

Figure 4. Picture of Group Five's work: Development of a Real-Time Dust Level Detection Device in the Classroom to Study Classroom Cleanliness

Table 4. The Pearson's correlation coefficient of observed variables.

Factors	Obs1	Obs2	Obs3	Que1	Que2	Qus3	Net1	Net2	Net3	Net4	Exp1	Exp2	Exp3
Obs1	1												
Obs2	0.444*	1											
Obs3	0.288	0.382*	1										
Que1	0.408*	0.720**	0.655**	1									
Que2	0.416*	0.484**	0.313	0.453*	1								
Que3	0.389*	0.384*	0.406*	0.504**	0.285	1							
Net1	0.621**	0.565**	0.467*	0.513**	0.479**	0.183	1						
Net2	0.33	0.471**	0.428*	0.510**	0.613**	0.026	0.657**	1					
Net3	0.420*	0.434*	0.394*	0.434*	0.636**	0.309	0.507**	0.686**					
Net4	0.253	0.367	0.286	0.385*	0.625**	0.572**	0.205	0.272	0.477**				
Exp1	0.579**	0.346	0.395*	0.573**	0.673**	0.465*	0.519**	0.607**	0.475**	0.612**	1		
Exp2	0.527**	0.386*	0.532**	0.508**	0.482**	0.352	0.484**	0.563**	0.450*	0.585**	0.735**	1	.
Exp3	0.609**	0.550**	0.458*	0.634**	0.720**	0.352	0.675**	0.647**	0.532**	0.642**	0.832**	0.753**	1

Note: *. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 4 shows the analysis of the relationship between the observed variables of Innovative Thinking, consisting of Observing, Questioning, Networking, and Experimenting, a total of 13 variables, using Pearson's correlation coefficient, found that the correlation coefficients ranged from .026 to .832, a total of 78 pairs. The correlation coefficients between variables with statistically significant values different from zero (p<.01) were 42 pairs, and the correlation coefficients between variables with statistically significant values different from zero (p<.05) were 21 pairs. The correlation coefficients between variables with statistical significance ranged from .384 to .832. The variables with the highest statistically significant relationship were when learning, I actively search for new ideas through experimenting (Exp1), and I actively search for new ideas through experimenting (Exp3). The variables with the lowest statistically significant relationship were new ideas often come to me when observing how other learners interact and do things (Obs2), and other learners are challenged by my questions (Que3), and all pairs had a positive relationship. The results indicated that the relationship between 15 pairs was not significant.

Table 5. The Pearson's correlation coefficient of innovative thinking variables.

Factors	Observing	Questioning	Networking	Experimenting
Observing	1			
Questioning	0.801**	1		
Networking	0.700**	0.700**	1	
Experimenting	0.682**	0.730**	0.782**	1

Note: **. Correlation is significant at the 0.01 level (2-tailed).

Table 5 shows the results of the analysis of the relationship between the four variables of Innovative Thinking, consisting of Observing, Questioning, Networking, and Experimenting, using Pearson's correlation coefficient, found that the correlation coefficients ranged from 0.682 to 0.801. The correlation coefficients between variables with statistically significant values different from zero (p<.01) were 6 pairs. The variables with the highest statistically significant relationship were Observing and Questioning (0.801). The variables with the lowest statistically significant relationship were Observing and Experimenting (0.682), both of which had a positive relationship.

5. DISCUSSIONS AND CONCLUSIONS

Project-based learning (PjBL) significantly enhances innovative thinking by fostering an engaging, collaborative, and real-world problem-solving environment. Research indicates that PjBL methodologies, such as those implemented in electro-mechanical engineering and information technology education, lead to substantial improvements in critical thinking, creativity, and problem-solving skills, with reported increases of 25% to 30% in these areas, respectively (Lubna et al., 2024; Mahtani et al., 2024). Additionally, innovative PjBL strategies in elementary education have shown to create interactive learning experiences that stimulate students' understanding and application of key concepts (Nugraha & Mardiyati, 2024). The incorporation of diverse backgrounds in group settings further enriches the learning process, promoting teamwork and collaborative innovation (Mashfufah et al., 2024). Overall, PjBL not only enhances academic performance but also equips students with essential skills for the digital era, thereby bridging the gap between traditional education and the demands of modern innovation (Widodo, 2024).

Students can enhance the success of their projects by incorporating innovative thinking through various strategies outlined in the research papers. Firstly, students should be trained in innovative thinking through pedagogical technologies like innovative projects, brainstorming methods, and problem-based tasks, enabling them to master the system of values and models of creative activity (Anufrieva et al., 2020). Additionally, a combination of design and scientific tools can provide an effective framework for students to visualize, understand, and express their progress in innovative projects, ensuring a successful user-product interaction (Apud-Bell, Dasan, & Childs, 2018). Moreover, educators should weave opportunities throughout students' undergraduate experience to facilitate the development of innovative thinking skills, allowing them to contribute innovative solutions in future workplace settings (Amelink, Davis, & Watford, 2019). By embracing these approaches, students can infuse their projects with innovative thinking, leading to more successful outcomes.

Innovative thinking significantly enhances student project work by fostering creativity, collaboration, and critical problem-solving skills across various educational contexts. Research indicates that PBL effectively cultivates these competencies, as it encourages students to engage actively with real-world challenges, thereby enhancing their creative cognition and adaptability (Lubna et al., 2024; Yu, 2024). The integration of technology and authentic assessments within PjBL frameworks has been shown to create more interactive and engaging learning environments, particularly in elementary education (Nugraha & Mardiyati, 2024). Furthermore, innovative learning models, including digital tools and STEAM approaches, have been linked to improved student motivation and collaborative skills, which are essential for successful project outcomes (Juliangkary, Suparta, Ardana, & Mahayukti, 2024). Studies also highlight the importance of teacher facilitation in navigating cognitive challenges, ensuring that students can maximize their creative potential through structured project work (Arifatin, 2023). Overall, these findings underscore the transformative impact of innovative thinking on student project work, promoting a more dynamic and effective learning experience.

The relationship between PjBL and innovative thinking is significantly influenced by several key factors, including collaborative learning, real-world problem-solving, and the integration of design thinking. PjBL fosters teamwork, allowing students from diverse backgrounds to collaborate, which enhances their innovative abilities through shared perspectives and experiences (Mashfufah et al., 2024). Additionally, PjBL encourages students to engage in hands-on projects that require creative thinking and experimentation, thereby promoting their problem-solving skills and overall creativity (Ndiung & Menggo, 2024; Sucilestari, Ramdani, Sukarso, Susilawati, & Rokhmat, 2023). The adaptability of PjBL to various cognitive styles and its emphasis on emotional engagement further support the development of innovative thinking by motivating students and enhancing their cognitive engagement (Yu, 2024). Moreover, incorporating design thinking into PjBL provides a structured approach to problem-solving, reinforcing the connection between creativity and practical application in real-world contexts (Liu & Niu, 2022).

This study emphasizes the importance of employing effective teaching techniques, such as project-based learning, to organize educational activities that foster innovative thinking among student teachers in the Digital Technology for Education program at Nakhon Sawan Rajabhat University. This approach enables students to think creatively and develop projects applicable in real-world contexts. For example, one project involved developing a system to detect Thai consonant pronunciation in Group 8. This group examined issues related to the current assessment methods used by teachers, which rely solely on headphones to evaluate pronunciation in kindergarten children. Such methods may not meet standard accuracy, and factors like teacher fatigue or mood could influence scoring reliability. Consequently, the group sought to create a standardized assessment method by designing a speech recognition system that records and trains sound data, establishing standard criteria for pronunciation evaluation. They utilized sound recording software, converted audio data, and employed spreadsheets to generate graphs and summarize scores. Another group focused on developing a nervousness detection system in learning environments. Recognizing that teachers and observers often struggle to accurately assess student nervousness, the students researched physiological indicators such as heart rate and body temperature, which tend to increase when a person is excited or nervous. Applying the concept of DIY smartwatches, they integrated various sensors and coding to monitor temperature and heart rate, testing the system with students and comparing results with normal individuals. These projects demonstrate how innovative technological solutions can enhance educational assessment and student well-being, aligning with the goals of fostering creativity and practical application in teacher training programs.

The above are just the innovative works of only two groups of students. From this teaching, all eight groups of students have developed innovations that are useful and can be applied in real educational institutions. The projects of Group 3, Development of Panic and Nervousness Detection Devices with DIY Smart Watch for Student Learning, and Group 1, Development of Real-Time Automatic Vehicle Noise Detection, have been published in the proceedings of the 7th National Conference on Teacher Education at Uttaradit Rajabhat University in 2025.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethical Committee of the Nakhon Ratchasima Rajabhat University, Thailand has granted approval for this study on 12 October 2023 (Ref. No. HE-222-2566).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

REFERENCES

Adilmurdin, R. R., & Laikov, E. G. (2023). Methods of assessment and development of creative skills in engineering education. https://doi.org/10.25726/n8521-7487-6197-u

Amelink, C. T., Davis, K. A., & Watford, B. (2019). Learning experiences that facilitate innovation and workforce preparation: Exploring the impact of in-class and extracurricular activities. *International Journal of Engineering Education 35*, 1642-1655. https://doi.org/10.18260/1-2--22825

Anufrieva, N. I., Ivanova, E. Y., Pereverzeva, M. V., Cheshenko, L. I., & Ovsyannikova, V. A. (2020). Innovative project thinking of designers as a pedagogical issue. *Universal Journal of Educational Research*, *8*(5), 1964-1968. https://doi.org/10.13189/UJER.2020.080533

Apud-Bell, M. J., Dasan, A., & Childs, P. R. (2018). *A combination of design- and scientific- led processes can be a successful approach towards building innovative projects*. Paper presented at the Proceedings of the 20th International Conference on Engineering and Product Design Education (E&PDE 2018), Dyson School of Engineering, Imperial College, London. 6th - 7th September 2018.

Arifatin, F. W. (2023). Project-based learning to enhance students' creative thinking skill on language learning. *Linguistics*, *9*(2), 260. https://doi.org/10.29300/ling.v9i2.3854

Ayyanathan, N. (2022). Learning analytics model and Bloom's taxonomy based evaluation framework for the post graduate students' project assessment – a blended project based learning management system with Rubric referenced predictors. *Shanlax International Journal of Education*, *10*(3), 48-60. https://doi.org/10.34293/education.v10i3.4766

Baradaran, M., Khosravipour, B., Rafe, M., Moosavi, S., & Roozbahani, M. (2015). Analyzing effect of teachers' creativity education on students academic achievement in secondary schools. *International Journal of Advanced Biological and Biomedical Research*, *3*(4), 326-331. https://doi.org/10.18869/IJABBR.2015.326

Barak, M., Watted, A., & Haick, H. (2020). Establishing the validity and reliability of a modified tool for assessing innovative thinking of engineering students. *Assessment & Evaluation in Higher Education*, *45*(2), 212-223. https://doi.org/10.1080/02602938.2019.1620680

Barron, B., & Darling-Hammond, L. (2008). *Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning (PDF). Powerful Learning: What We Know About Teaching for Understanding*. San Francisco, CA: Jossey-Bass.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, *83*(2), 39-43.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, *26*(3-4), 369-398.

Brooks-Young, S. (2010). 21st -century skills. In Teaching with the Tools Kids Really Use: Learning with Web and Mobile Technologies. In (pp. 5-12): Corwin Press, https://doi.org/10.4135/9781452219455.

Caniago, M. (2024). A meta-analysis approach to measure the impact of project based learning outcome. *Deleted Journal*, *2*(1), 34–47. https://doi.org/10.33830/cocatalyst.v2i1.9599

Cavichioli, P. L., Conceição, M. H., & Costa, A. A. (2024). Development of competencies for innovation: A comparative study between Brazil and Germany. *Seven Editora*, 141–161. https://doi.org/10.56238/sevened2024.031-009

Darling-Hammond, L., Barron, B., Pearson, P. D., Schoenfeld, A. H., Stage, E. K., Zimmerman, T. D., . . . Tilson, J. L. (2008). *Powerful learning: What we know about teaching for understanding*. San Francisco, CA: Jossey-Bass.

Delhi, A., Sana, E., Angelina Bisty, A., & Husain, A. (2024). Innovation in business management exploring the path to competitive excellence. *APTISI Transactions on Management*, *8*(1), 58–65. https://doi.org/10.33050/atm.v8i1.2204

Devaki, V. (2024). Exploring the impact of innovative assessment methods on learning outcomes. *Policy Development, Curriculum Design, and Administration of Language Education*, 343-374. https://doi.org/10.4018/979-8-3693-3645-8.ch015

Dighliya, B. (2025). Innovative teaching methods for skill development. In M. Kayyali & B. Christiansen (Eds.), Insights Into International Higher Education Leadership and the Skills Gap. In (pp. 229-250): IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-3443-0.ch009.

Ertmer, P. A., & Simons, K. D. (2006). Jumping the PBL implementation hurdle: Supporting the efforts of K–12 teachers. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1), 40-54. https://doi.org/10.7771/1541-5015.1005

Fasel Mkawin, S. A.-K. (2022). The role of the teacher in developing creativity and innovative thinking among students in the education of Liwa al-Muwaqar from their point of view. *Journal of Education and Practice*, *13*(18), 57-68. https://doi.org/10.7176/jep/13-18-06

Gopinathan, S., Kaur, A. H., Ramasamy, K., & Raman, M. (2022). Enhancing innovative delivery in schools using design thinking. *F1000Research*, *10*, 927. https://doi.org/10.12688/f1000research.72860.3

Hawthorne, G., Saggar, M., Quintin, E.-M., Bott, N. T., Keinitz, E., Liu, N., . . . Reiss, A. L. (2016). Designing a creativity assessment tool for the twenty-first century: Preliminary results and insights from developing a design-thinking based assessment of creative capacity. In (pp. 111–123). Cham: Springer.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational psychology review*, *16*, 235-266.

Ioniţă, C. G. (2022). *Exploration vs. exploitation: How innovation strategies impact firm performance and competitive advantage*. Paper presented at the Proceedings of the International Conference on Business Excellence. The Bucharest University of Economic Studies, vol. 16 no. 1, pp. 31-46. https://doi.org/10.2478/picbe-2022-0006.

Juliangkary, E., Suparta, I. N., Ardana, I. M., & Mahayukti, G. A. (2024). Development of learning models to enhance students' creative thinking: A systematic literature review. https://doi.org/10.59175/pijed.v3i2.333

Kadarisman, M., Asnah, M. N. L., & Suryo, P. (2022). Training on the development of utilization of digital teaching materials for teachers to improve student learning outcomes. *Jurnal Teknologi Pendidikan*, *24*(3), 400–411. https://doi.org/10.21009/jtp.v24i3.31799

Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences. In (2nd ed., pp. 275-297). Cambridge, UK: Cambridge University Press.

Larmer, J., Mergendoller, J., & Boss, S. (2015). *Setting the standard for project based learning*. Alexandria, VA: Ascd.

Li, L. (2022). Innovative thinking in E-commerce teaching. *Cross-Border Trade and E-commerce*, *1*(1), 5-8. https://doi.org/10.55571/cte.2022.05012

Liu, H., & Niu, Y. (2022). *The construction of project-based learning model based on design thinking*. Paper presented at the Proceedings of the 2022 5th International Conference on Computer Science and Technology Engineering (CSTE), 173–177. https://doi.org/10.1109/CSTE55932.2022.00038.

Lubna, L., Suhirman, S., & Prayogi, S. (2024). Hybrid information technology learning based on project work to enhance students' design thinking in creating digital innovations. *International Journal of Learning, Teaching and Educational Research*, *23*(8), 447-467. https://doi.org/10.26803/ijlter.23.8.23

Mahtani, K., Guerrero, J. M., & Decroix, J. (2024). Implementing innovation in project-based learning in electro-mechanical engineering education. *International Journal of Mechanical Engineering Education*, 03064190241284600. https://doi.org/10.1177/03064190241284600

Manji, D. A., & Laghari, I. S. (2022). Innovation strategies and corporate performance: Perspective from India. *Journal of Strategic Management*, *6*(5), 11–26. https://doi.org/10.53819/81018102t4063

Mashfufah, A., Rufiana, I. S., Arifin, S., Ekawati, R., Sari, D. R., & Salam, H. (2024). Project-based learning with paired expert and beginner models to develop innovative thinking skills. *Journal for Lesson and Learning Studies*, *7*(2), 212-220. https://doi.org/10.23887/jlls.v7i2.74482

Moon, T. R., Brighton, C. M., & Hock, M. (2022). *Project-based tasks for assessment of gifted learners. In S. Johnsen & J. VanTassel Baska (Eds.), Assessment in gifted education: A Handbook* (1st ed.). New York, USA: Taylor & Francis, Routledge.

Mugione, F., & Penaluna, A. (2018). *Developing and evaluating enhanced innovative thinking skills in learners. In: James, J., Preece, J., Valdés-Cotera, R. (eds) Entrepreneurial Learning City Regions.* Cham: Springer.

Muldagaliyeva, A. A., Dosmagambetova, D., & Kulzhanbekova, G. K. (2023). Competencies of the 21st century. What are they and why are they important. *Вестник КазНУ. Серия филологическая*, *189*(1), 203–209.

Ndiung, S., & Menggo, S. (2024). Project-based learning in fostering creative thinking and mathematical problem-solving skills: Evidence from primary education in Indonesia. *International Journal of Learning, Teaching and Educational Research*, *23*(8), 289-308. https://doi.org/10.26803/ijlter.23.8.15

Ness, R. B. (2015). Promoting innovative thinking. *American journal of Public Health*, *105*(S1), S114-S118. https://doi.org/10.2105/AJPH.2014.302365

Niruttimatee, P. K., & Sanrattana, W. (2022). An online program to develop teachers to enhance the innovation skills of students. *Education Quarterly Reviews*, *5*(2), 533-543.

Nugraha, M. T., & Mardiyati, I. (2024). Innovations in project-Based learning (PBL strategies for elementary school students. *International Journal of Basic Educational Research*, *1*(2), 35-40. https://doi.org/10.14421/ijber.v1i2.9645

Partnership for 21st Century Skills. (2009). *P21 framework definitions. Partnership for 21st century skills.* Retrieved from https://www.battelleforkids.org/

Ramamonjisoa, D. (2024). Equipping students for a dynamic future. *PUPIL: International Journal of Teaching, Education and Learning*, *8*(2), 32-48. https://doi.org/10.20319/pijtel.2024.82.3248

Rasulova, T. P. (2024). Project-based learning as an innovative approach to developing practical skills and professional competences in students of technical universities. *International Journal of Pedagogics, 4*(10), 143-148. https://doi.org/10.37547/ijp/volume04issue10-24

Ritambhara, & Singh, S. N. (2023). *Creativity: Mining of innovative thinking using educational data.* Paper presented at the 2023 International Conference on Disruptive Technologies (ICDT), Greater Noida, India, 2023, p. 445-449.

Shenhar, A., Holzmann, V., Dvir, D., Shabtai, M., Zonnenshain, A., & Orhof, O. (2020). If you need innovation success, make sure you've got the right project. *IEEE Engineering Management Review, 48*(1), 113-126. https://doi:10.1109/EMR.2020.2974698

Sina Setyadi, M. C., & Woro Hastuti, A. (2024). Organizational innovation as a mediation of the influence of innovation capability on organizational performance in manufacturing companies in East Java. *KnE Social Sciences*, *9*(29), 73–83. https://doi.org/10.18502/kss.v9i29.17239

Sokerina, E. (2021). Mechanisms triggering innovative mental activities: Analytical, logical, imaginative, and critical thinking in innovation-oriented companies. *Journal of Innovation and Business Management*, *10*(6), 34-37.

Sucilestari, R., Ramdani, A., Sukarso, A., Susilawati, S., & Rokhmat, J. (2023). Project-based learning supports students' creative thinking in science education. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1038-1044. https://doi.org/10.29303/jppipa.v9i11.5054

Sukkeewan, P., Songkram, N., & Nasongkhla, J. (2024). Development and validation of a reliable and valid assessment tool for measuring innovative thinking in vocational students. *International Journal of Educational Methodology*, *10*(1), 835-844. https://doi.org/10.12973/ijem.10.1.835

Thomas, J. W. (2000). A review of research on project-based learning.

Todorova, S. (2024). 21st century skills in the context of education. *Cultural and Historical Heritage: Preservation, Presentation, Digitalization (KIN Journal)*, *10*(1), 101-110. https://doi.org/10.55630/KINJ.2024.100109

Vittorio, R., Rajuddin, W. O. N., & Dewi, N. L. Y. (2024). Enhancing performance and productivity through innovation in business management. *Implikasi: Jurnal Manajemen Sumber Daya Manusia*, *2*(1), 11-18. https://doi.org/10.56457/implikasi.v2i1.550

Vyacheslavovna, S. S. (2022). Formation and development of employee thinking in innovation-oriented companies. *Management of the Personnel and Intellectual Resources in Russia*, *10*(6). https://doi.org/10.12737/2305-7807-2022-10-6-34-37

Wang, A., & Burdina, G. (2024). Developing students' creative thinking using innovative education technologies. *Interactive Learning Environments*, *32*(7), 3490-3500. https://doi.org/10.1080/10494820.2023.2184390

Wang, J., & Zhu, Y. (2015). *The cultivation of students' innovative thinking ability in the college English teaching*. Paper presented at the 2015 International Conference on Social Science, Education Management and Sports Education (pp. 837-1839). Atlantis Press.

Widodo, J. P. (2024). Unleashing student potential: Enhancing creativity and performance with project-based learning. *Jurnal Sosioteknologi*, *23*(2). https://doi.org/10.5614/sostek.itbj.2024.23.2.1

Wisetsat, C., & Nuangchalerm, P. (2019). Enhancing innovative thinking of Thai pre-service teachers through multi-educational innovations. *Journal for the Education of Gifted Young Scientists*, *7*(3), 409-419. https://doi.org/10.17478/JEGYS.570748

Yu, H. (2024). Enhancing creative cognition through project-based learning: An in-depth scholarly exploration. *Heliyon*. https://doi.org/10.1016/j.heliyon.2024.e27706