

Effect of the 4Cs on project-based learning in digital education: evidence from private universities in Thailand

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Received: February 6, 2026; Revised: May 18, 2026; Accepted: May 30, 2026

ABSTRACT

This study examines the effect of integrating the 4Cs—critical thinking, creativity, communication, and collaboration—into project-based learning in digital education at private universities in Thailand. Using a quantitative research design, data were collected from 500 undergraduate students with experience in digital project-based learning through a structured five-point Likert-scale questionnaire. Descriptive statistics and multiple linear regression were used for data analysis. The results showed moderate to high levels of 4C integration and revealed that all four competencies have positive and statistically significant effects on learning outcomes. The regression model explained 72.8% of the variance in learning outcomes, indicating strong explanatory power. Critical thinking and collaboration were the strongest predictors, followed by creativity and communication. These findings provided empirical evidence that embedding the 4Cs in digital project-based learning enhances students' learning outcomes. The study contributes to digital pedagogy by validating the 4Cs framework in Thai private higher education and highlights the need for instructional designs that prioritize 21st-century skill development alongside technology use.

KEYWORDS: Digital education; Project-based learning; 4Cs; Learning outcomes; Private universities

Introduction

The rapid expansion of digital education has transformed how teaching and learning are designed, delivered, and evaluated. Advances in educational technologies, online platforms, and digital resources have broadened access to learning and reshaped pedagogical practice (Haleem et al., 2022; Mahmadoy, 2025; Zou et al., 2025). Beyond content delivery, digital education is increasingly expected to develop 21st-century competencies that enable learners to succeed in complex, technology-driven environments. Among these competencies, the 4Cs—critical thinking,

creativity, communication, and collaboration are widely recognized as essential for academic success, employability, and lifelong learning (Ahmed, 2022; Tuazon & Sumadsad, 2022; Thornhill-Miller et al., 2023).

Project-based learning has emerged as an effective pedagogical approach for developing higher-order thinking and transferable skills by engaging learners in authentic, problem-centered tasks. Through inquiry, collaboration, and reflective practice, project-based learning encourages learners to actively construct knowledge while applying it to real-world contexts. When implemented

in digital education settings, project-based learning offers additional opportunities to integrate technology-mediated collaboration, communication, and creative problem-solving (Almulla, 2020; Azimi, 2025; Julaeha, 2025; Sánchez-García & Reyes-de-Cózar, 2025).

Although scholarship on digital education and project-based learning continues to grow, limited empirical attention has been given to the explicit integration of the 4Cs within digital project-based learning environments. This gap is particularly evident in Thai private higher education, where digital learning has expanded rapidly in response to technological advancement and educational reform. Many private universities still face challenges in systematically developing students' 21st-century competencies, and evidence on the pedagogical effectiveness of embedding the 4Cs in digital project-based learning remains limited.

Accordingly, this study investigates the integration of the 4Cs into project-based learning in digital education at private universities in Thailand. Using multiple linear regression, it examines whether critical thinking, creativity, communication, and collaboration significantly predict positive learning outcomes. The study contributes empirical evidence to the literature on digital pedagogy and project-based learning and offers practical insights for educators and institutions seeking to design learning environments that foster 21st-century skills.

Purpose

To examine the effects of the 4Cs on learning outcomes in digital project-based learning among undergraduate students at private universities in Thailand.

Benefit of Research

This research offers theoretical and practical contributions. Theoretically, it extends the digital education literature by providing empirical evidence on how the 4Cs

influence learning outcomes in project-based learning. Practically, the findings offer educators, instructional designers, and policymakers evidence-based guidance for designing digital project-based learning that promotes critical thinking, creativity, communication, and collaboration. The results may also inform curriculum development and professional training aimed at strengthening 21st-century competencies in digital learning environments.

Literature Review

This literature review synthesizes prior studies on the 4Cs, project-based learning, and digital education. By bringing together these strands of literature, the review establishes a conceptual foundation for understanding the role of digital project-based learning in fostering critical thinking, creativity, communication, and collaboration.

The 4Cs as Core 21st-Century Skills

The concept of the 4Cs—critical thinking, creativity, communication, and collaboration—has been widely recognized as a foundational framework for 21st-century learning. International organizations and educational scholars emphasize that these competencies are essential for learners to adapt to complex, technology-driven societies and dynamic labor markets. Critical thinking enables learners to analyze problems and make informed decisions, creativity supports innovation and idea generation, communication facilitates effective knowledge exchange, and collaboration enhances teamwork and collective problem-solving. In higher education, the development of the 4Cs has become a strategic priority, particularly as institutions seek to prepare graduates for professional environments characterized by uncertainty and digital transformation (Ahmed, 2022; Azmi et al., 2024; Thornhill-Miller et al., 2023).

Project-Based Learning and Skill Development

Project-based learning is a learner-centered pedagogical approach that engages students in authentic, inquiry-driven projects requiring sustained effort, problem solving, and reflection. Prior studies consistently report that project-based learning enhances student engagement, motivation, and deeper learning by encouraging learners to apply knowledge in real-world contexts. Importantly, project-based learning is strongly associated with the development of higher-order thinking skills and transversal competencies, including the 4Cs. Through collaborative project work, students are required to communicate ideas, negotiate roles, think critically about solutions, and demonstrate creativity in project outcomes. As a result, project-based learning is frequently identified as a pedagogical model well aligned with 21st-century skill development (Martinez, 2022; Maros et al., 2023; Ka-J et al., 2023; Saimon et al., 2023; Vaithianathan et al., 2024).

Digital Education and Project-Based Learning

The integration of digital technologies into education has further expanded the potential of project-based learning. Digital education environments provide tools and platforms that support collaboration, communication, and content creation beyond the constraints of time and place. Online learning management systems, cloud-based collaboration tools, and other digital platforms enable students to work collaboratively, access diverse resources, and present project outcomes in innovative formats, thereby improving learning outcomes. Research suggests that digital project-based learning can enhance learner autonomy and flexibility while supporting interactive and collaborative learning processes. However, the effectiveness of digital project-based learning depends heavily on instructional design and the extent to which learning activities intentionally foster targeted competencies (Al-Samarraie &

Saeed, 2018; Alshammary & Alhalafawy, 2023; Evenddy et al., 2023; Hoesny et al., 2024; Xudayberdiyevna, 2024).

Hypotheses Development

Based on the literature on the 4Cs, project-based learning, and digital education, this study proposes that integrating critical thinking, creativity, communication, and collaboration into digital project-based learning positively influences learning outcomes among undergraduate students in private universities in Thailand. Prior studies suggest that these competencies are essential for enhancing student engagement, higher-order thinking, and effective knowledge construction in technology-supported learning environments (Ahmed, 2022; Thornhill-Miller et al., 2023; Tuazon & Sumadsad, 2022). Project-based learning further provides opportunities for students to apply these competencies through authentic and collaborative learning activities (Martinez, 2022; Maros et al., 2023).

Collaboration is considered a key element of project-based learning because it encourages teamwork, shared problem-solving, and active participation in learning activities. Digital platforms also facilitate collaborative interaction through online communication and cloud-based tools, which may improve students' learning experiences and outcomes (Al-Samarraie & Saeed, 2018; Vaithianathan et al., 2024). Therefore, the following hypothesis is proposed:

H1: Collaboration positively affects learning outcomes in digital project-based learning.

Critical thinking is widely recognized as an essential competency for analyzing information, evaluating alternatives, and solving complex problems. In project-based learning environments, students are required to engage in inquiry, reflection, and decision-making processes that strengthen analytical reasoning skills (Tafakur et al., 2023). Digital learning environments further support access

to information and interactive tools that can enhance critical thinking development. Thus, the following hypothesis is proposed:

H2: Critical thinking positively affects learning outcomes in digital project-based learning.

Creativity is another important competency fostered through project-based learning, as students are encouraged to generate innovative ideas, develop original solutions, and create meaningful project outputs. Digital technologies provide opportunities for multimedia creation, flexible learning activities, and creative expression, which may contribute to improved educational outcomes (Julaeha, 2025; Xudayberdiyevna, 2024). Accordingly, the following hypothesis is proposed:

H3: Creativity positively affects learning outcomes in digital project-based learning.

Communication plays a crucial role in project-based learning because students must exchange ideas, present findings, and interact effectively with peers and instructors. Digital education environments support communication through online discussions, collaborative platforms, and virtual presentations, which can strengthen learning engagement and understanding (Evenddy et al., 2023). Therefore, the following hypothesis is proposed:

H4: Communication positively affects learning outcomes in digital project-based learning.

Figure 1 presents the conceptual framework of the study.

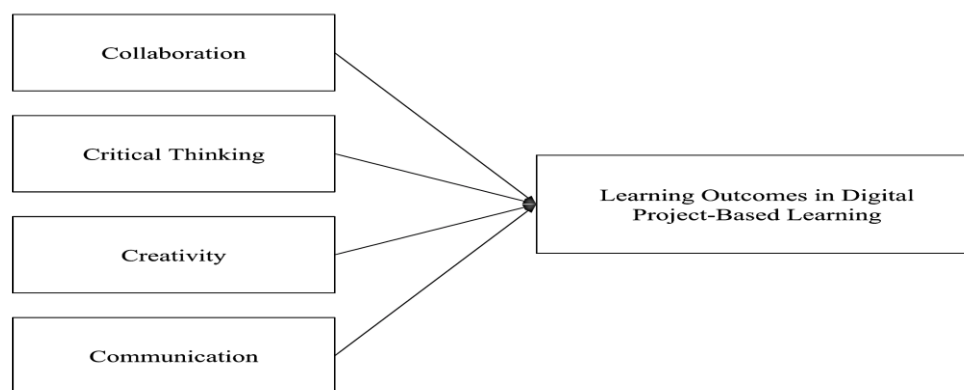


Figure 1. Conceptual Framework

The framework in Figure 1 proposes that the integration of the 4Cs—collaboration, critical thinking, creativity, and communication—within digital project-based learning positively enhances students' learning outcomes in private universities in Thailand.

Research Process

This study employed a quantitative research design to investigate the integration of the 4Cs into project-based

learning in digital education within private universities in Thailand.

Population and Sample

The target population consisted of undergraduate students enrolled in private universities in Thailand, ranging from first-year to fourth-year students, who had prior experience with digital project-based learning activities. Convenience sampling was employed to recruit participants. The minimum sample size was determined using Cochran's formula at a 95%

confidence level and a 0.05 margin of error, resulting in a required sample size of 384 participants. To ensure adequate statistical power and to account for potential incomplete responses, a total of 500 valid questionnaires were collected and included in the final analysis.

Instruments

Data were collected using a structured questionnaire developed based on relevant literature on the 4Cs, project-based learning, and digital education. Measurement items were measured using a five-point Likert scale. The questionnaire was reviewed by three experts in social sciences and digital education management to ensure clarity, content validity, and alignment with the study objectives prior to data collection. The reliability analysis demonstrated excellent internal consistency, with a Cronbach's alpha coefficient of 0.94, exceeding the recommended threshold of 0.70.

Data Collection

Data were collected through an online survey distributed via widely used digital communication platforms in Thailand, including Facebook and LINE. A mobile-friendly questionnaire format was employed to enhance accessibility and participation. Data collection was conducted between November and December 2025 to capture students' recent experiences with digital project-based learning.

Participants were informed of the study's objectives and assured that the data would be used solely for academic purposes. The study involved non-medical, anonymous survey research with participants aged 18 years or older and did not include vulnerable populations. Informed consent was obtained electronically prior to participation. Anonymity and confidentiality were strictly maintained, and no personally identifiable information was collected. In accordance

with the guidelines issued by Thailand Science Research and Innovation (TSRI), behavioral and social science research employing anonymous data collection instruments and posing no risk to participants is exempt from formal ethics committee approval. This study met the criteria for such exemption and adhered to recognized ethical standards.

Data Analysis

Data were analyzed using Jamovi, an open-source statistical software widely used in behavioral and social science research. Descriptive statistics were used to summarize demographic characteristics and variable distributions. Multiple linear regression analysis was conducted to examine the relationships between the 4C constructs and learning outcomes in project-based learning within digital education at private universities in Thailand.

Results

The study's participants comprised 500 undergraduate students from private universities in Thailand. Female students accounted for 56.4% of the respondents, while 43.6% were male. In terms of year of study, 24.8% were first-year students, 26.2% were second-year students, 25.6% were third-year students, and 23.4% were fourth-year or final-year students. Regarding fields of study, 32.0% of participants were enrolled in business and management programs, 27.6% in social sciences and humanities, 21.4% in information technology and digital-related programs, and 19.0% in education and other related disciplines. All respondents reported prior experience with project-based learning in digital education environments, indicating that the sample was well suited to assess the integration of the 4Cs in digital project-based learning. The demographic distribution reflects a diverse and representative sample of undergraduate students in private universities in Thailand.

Table 1: Descriptive Statistics

	N	Mean	Std. Deviation
Collaboration	500	3.317	0.999
Critical Thinking	500	3.296	1.008
Creativity	500	3.306	1.009
Communication	500	3.313	1.000

Table 1 presents the descriptive statistics for the four core constructs of the 4Cs—collaboration, critical thinking, creativity, and communication—as perceived by undergraduate students participating in digital project-based learning. The results indicate that the mean scores for all four constructs are above the midpoint of the five-point Likert scale, suggesting a generally positive perception of 4C integration within digital learning environments. Collaboration reported the

highest mean score ($M = 3.317$, $SD = 0.999$), followed closely by communication ($M = 3.313$, $SD = 1.000$) and creativity ($M = 3.306$, $SD = 1.009$). Critical thinking showed a slightly lower but still comparable mean ($M = 3.296$, $SD = 1.008$). The relatively similar standard deviations across constructs indicate a consistent level of variability in students' responses, suggesting that participants shared comparable experiences regarding the development of the 4Cs through digital project-based learning.

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1 ^a	0.853 ^a	0.728	0.725	0.55949

a. Predictors: (Constant), Communication, Collaboration, Creativity, Critical Thinking

Table 2 summarizes the overall fit of the regression model examining the relationship between the four 4C dimensions and learning outcomes in digital project-based learning. The model demonstrates a strong correlation between the independent variables and learning outcomes ($R=0.853$). The coefficient of determination ($R^2 = 0.728$) indicates that approximately 72.8% of the variance in learning outcomes can be explained by collaboration, critical thinking, creativity,

and communication. The adjusted R^2 value (0.725) further confirms the robustness of the model after accounting for the number of predictors. Additionally, the relatively low standard error of the estimate (0.55949) suggests that the model provides accurate predictions of learning outcomes, indicating a strong explanatory power of the 4Cs within the digital project-based learning context.

Table 3: Analysis of Variance

Model		Sum of Squares	df	Mean Square	F	Sig.
1 ^a	Regression	413.738	4	103.435	330.429	< 0.001 ^b
	Residual	154.950	495	0.313		
	Total	568.689	499			

a. Dependent Variable: Learning Outcomes in Project-Based Learning

b. Predictors: (Constant), Communication, Collaboration, Creativity, Critical Thinking

Table 3 reports the results of the analysis of variance (ANOVA) used to assess the overall statistical significance of the regression model. The findings reveal that the model is highly significant ($F = 330.429$, $p < 0.001$), indicating that the set of predictor variables collectively explains a substantial proportion of variance in learning outcomes. The regression sum of squares (413.738) is considerably larger than

the residual sum of squares (154.950), further demonstrating that the inclusion of the four 4C constructs significantly improves the model's ability to predict learning outcomes. These results confirm that the regression model is appropriate and statistically valid for examining the effects of integrating the 4Cs into digital project-based learning.

Table 4: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1 ^a	(Constant)	0.063	0.093		0.678	0.498
	Collaboration	0.258	0.052	0.241	4.968	< 0.001
	Critical Thinking	0.282	0.051	0.266	5.517	< 0.001
	Creativity	0.235	0.051	0.222	4.593	< 0.001
	Communication	0.205	0.046	0.192	4.433	< 0.001

a. Dependent Variable: Learning Outcomes in Project-Based Learning

The multiple regression equation indicates that learning outcomes in digital project-based learning can be predicted as follows:

$$Y = 0.063 + 0.258 (\text{Collaboration}) + 0.282 (\text{Critical Thinking}) + 0.235 (\text{Creativity}) + 0.205 (\text{Communication})$$

where Y represents learning outcomes in project-based learning. The equation demonstrates that collaboration, critical thinking, creativity, and communication all positively contribute to learning outcomes, with critical thinking showing the strongest predictive effect.

Table 4 presents the regression coefficients for each of the four 4C constructs and their individual contributions to learning outcomes in digital project-based learning. All predictors exhibit

positive and statistically significant effects ($p < 0.001$), indicating that higher levels of each 4C are associated with improved learning outcomes. Among the predictors, critical thinking demonstrates the strongest standardized effect ($\beta = 0.266$), followed by collaboration ($\beta = 0.241$), creativity ($\beta = 0.222$), and communication ($\beta = 0.192$). These findings suggest that while all four competencies play a significant role, critical thinking and collaboration exert relatively stronger influences on learning outcomes. Overall, the results underscore the importance of intentionally integrating the 4Cs into digital project-based learning designs to enhance students' educational outcomes in private universities in Thailand.

Discussion

This study investigated the effects of integrating the 4Cs—critical thinking, creativity, communication, and collaboration—into digital project-based learning at private universities in Thailand. The findings provide empirical support for this pedagogical approach, demonstrating that all four competencies significantly and positively influence students' learning outcomes.

The descriptive results show that students perceived moderate to high levels of 4C integration in digital project-based learning. This finding is consistent with prior studies indicating that project-based learning promotes collaboration, communication, and creative problem-solving, especially when supported by digital technologies (Almulla, 2020; Maros et al., 2023; Saimon et al., 2023). The relatively balanced mean scores across the four constructs suggest that digital project-based learning can support multiple 21st-century competencies simultaneously.

The regression results further indicate that the 4Cs explain a substantial proportion of variance in learning outcomes, confirming a strong predictive relationship between these competencies and students' perceived learning success. This supports previous research showing that digital education is most effective when technology is combined with instructional designs that foster higher-order skills rather than content delivery alone (Al-Samarraie & Saeed, 2018; Alshammary & Alhalafawy, 2023; Hoesny et al., 2024).

Critical thinking was the strongest predictor of learning outcomes. This result reinforces the role of analytical reasoning, evidence evaluation, and informed decision-making in project-based learning (Tafakur et al., 2023; Thornhill-Miller et al., 2023). In digital learning environments, access to diverse information sources and interactive tools may further strengthen students'

ability to analyze problems and develop reasoned solutions.

Collaboration also had a strong positive effect, highlighting the importance of teamwork, shared responsibility, and collective knowledge construction in digital project-based learning. This finding aligns with studies showing that collaborative learning improves engagement and problem-solving when supported by online communication tools and cloud-based platforms (Al-Samarraie & Saeed, 2018; Evenddy et al., 2023; Vaithianathan et al., 2024). In Thai private universities, such tools appear to play an important role in facilitating meaningful learning experiences.

Creativity and communication were also significant predictors, although their effects were slightly smaller than those of critical thinking and collaboration. These findings are consistent with research showing that project-based learning encourages students to generate original ideas, produce creative outputs, and communicate their work effectively (Martinez, 2022; Julaeha, 2025). Digital education expands these opportunities through multimedia production, online discussions, and virtual presentations, which can enhance motivation and learning effectiveness (Xudayberdiyevna, 2024; Yuanti et al., 2025).

Overall, the findings support theoretical perspectives that view the 4Cs as interconnected competencies essential for 21st-century learning (Ahmed, 2022; Tuazon & Sumadsad, 2022; Thornhill-Miller et al., 2023). They also extend prior research by demonstrating that purposeful 4C integration in digital project-based learning can improve learning outcomes in Thai private higher education, a context that remains underrepresented in empirical studies.

Conclusion

This study concludes that digital project-based learning is more effective when it intentionally integrates the 4Cs: critical thinking, creativity, communication, and collaboration. The findings show that all four competencies significantly enhance students' learning outcomes, with critical thinking and collaboration exerting the strongest effects.

Theoretically, the study validates the relevance of the 4Cs framework in digital higher education and provides context-specific evidence from Thai private universities. The results suggest that these competencies work together to strengthen learning outcomes when embedded in well-designed project-based learning activities.

Practically, the findings emphasize that technology adoption alone is insufficient. Educators and institutions should design digital project-based learning activities that deliberately cultivate higher-order thinking, teamwork, creative production, and effective communication.

As digital education continues to expand, systematic integration of the 4Cs can help universities create more meaningful, skill-oriented, and future-ready learning experiences.

Recommendations

Based on the findings, educators should design digital project-based learning activities that explicitly develop the 4Cs. Critical thinking can be promoted through problem analysis, evidence-based reasoning, and reflective tasks. Collaboration should be supported through clear group roles, shared digital workspaces, and assessment criteria that value teamwork. Creativity can be encouraged by allowing flexibility in project design, media use, and final outputs. Communication skills should be strengthened through online discussions, peer feedback, presentations, and structured interaction with instructors. Universities

should also provide professional development to help educators integrate digital tools with 4C-oriented pedagogy effectively.

Limitations and Future Research

Despite its contributions, this study has several limitations. First, its cross-sectional quantitative design limits causal interpretation. Future studies could use longitudinal designs to examine how critical thinking, creativity, communication, and collaboration develop over time in digital project-based learning environments. Second, the study relied on self-reported questionnaire data, which may be affected by response bias. Future research could incorporate interviews, classroom observations, or mixed-methods designs to gain deeper insight into students' learning experiences and behaviors.

Third, the sample was limited to undergraduate students from private universities in Thailand, which may restrict generalizability to public universities, vocational institutions, or international settings. Future studies should examine broader and more diverse populations. Fourth, this study focused on the direct effects of the 4Cs and did not examine mediating or moderating variables. Future research may explore digital literacy, student motivation, technological readiness, instructional quality, or learning engagement to provide a more comprehensive understanding of digital project-based learning effectiveness.

Finally, future studies may compare digital learning platforms, instructional strategies, and disciplinary contexts to identify which approaches most effectively support 4C integration in higher education. Such research would further advance digital pedagogy and 21st-century skill development in evolving educational environments.

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