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ENHANCING CRITICAL HINKING SKILLS THROUGH AGILE PROJECT-BASED LEARNING IN VOCATIONAL EDUCATION

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Abstract

This research explores the impact of integrating the *Project-Based Agile Learning (PjBL–Agile)* framework on the enhancement of vocational learners' critical thinking competencies. The investigation was carried out in two state vocational institutions located in Pacitan Regency—**SMK Negeri 1 Donorojo** and **SMK Negeri Pringkuku**—with a total of **106 students** majoring in Computer and Network Engineering. Participants were divided into **experimental** and **control** cohorts.The development of the instructional framework adopted the **Research and Development.** Data were gathered through pretest–posttest assessments, classroom observations, learner perception surveys, and reflective interviews.Findings revealed a consistent improvement in the experimental cohort's critical thinking performance, with the mean score increasing from **24.31 to 32.14**, while the control group showed only a marginal rise from **25.11 to 26.23**. The **N-Gain** index of **0.499** indicated a moderate level of improvement for the experimental group, whereas the control group achieved a low-level gain of **0.076**. Furthermore, results from the **independent *t*-test** confirmed a substantial difference between groups, $t(138) = 10.96$, $p < 0.001$.Qualitative evidence supported these numerical outcomes, demonstrating higher engagement, cooperation, and reflection among learners in the Agile-based setting. Collectively, the results highlight that the PjBL–Agile framework cultivates critical and adaptive thinking, while also strengthening collaborative and problem-solving abilities in 21st-century vocational contexts.

Keywords: *Project-Based Learning (PjBL), Agile Learning, Critical Thinking Skills, Vocational Education, 21st-Century Skills*

INTRODUCTION

The emergence of the Fourth Industrial Revolution has accelerated technological transformation across sectors through automation, robotics, artificial intelligence, and the Internet of Things (IoT). These advancements are reshaping human activity, influencing the ways people work, communicate, and acquire knowledge. Within this transformation, critical thinking is widely recognized as a fundamental skill for managing uncertainty, navigating complexity, and generating sustainable innovation (Khairunnisa & Ilmi, 2020; Pahrudin et al., 2021).

Education, therefore, holds a strategic role in cultivating learners' capacity for reasoning, reflection, and adaptive decision-making. Inquiry-based and interdisciplinary learning frameworks such as STEM have demonstrated the potential to strengthen analytical and creative thinking among students (Pahrudin et al., 2021). Likewise, the incorporation of digital learning tools enables more interactive and dynamic learning processes, although infrastructure and digital readiness remain key challenges (Khairunnisa & Ilmi, 2020).

In vocational education settings—particularly at vocational high schools—teaching practices tend to focus heavily on technical proficiency, which may limit opportunities for reflective and analytical engagement. Previous empirical studies have revealed that collaborative and participatory pedagogies can improve motivation, performance, and social responsibility among vocational learners (Ruijuan et al., 2023). Similarly, embedding reflective activities into instruction contributes to professional growth and learner autonomy (Mohamed et al., 2022; Rokayah et al., 2023).

In order to tackle these challenges, the Project-Based Learning (PjBL) approach has been adopted to cultivate 21st-century skills, specifically critical thinking, creativity, communication, and collaboration (4C). However, the effectiveness of PjBL is influenced by elements such as student preparedness, access to digital resources, and the adaptability of teachers (Meng et al., 2023; Mutanga, 2024; Rehman et al., 2024).

Building upon this, Agile Learning—originally a framework from software engineering—offers promising elements for education through its iterative and collaborative cycles. It emphasizes feedback loops, adaptability, and self-organization as mechanisms for continuous improvement. Empirical evidence has shown that integrating Agile frameworks, such as eduScrum and Agile Learning Loops, enhances engagement, communication, and critical reflection among learners (Pócsová et al., 2020; De Barros et al., 2023; Zahorodko, 2023).

According to Ennis (2011) and Facione (2015), critical thinking encompasses abilities such as interpretation, inference, analysis, and evaluation, as well as metacognitive reflection. Therefore, integrating Agile principles within PjBL offers potential to create an adaptive and learner-driven instructional design. This study focuses on analyzing the effectiveness of this PjBL–Agile integrated framework in improving vocational students' critical thinking skills, highlighting how iterative collaboration and structured reflection can foster deeper, more autonomous learning outcomes.

LITERATURE REVIEW

In today's technology-driven era, the ability to think critically has evolved into a vital competency for continuous learning, innovation, and adaptability. This skill empowers individuals to evaluate evidence, synthesize information, and make informed judgments within increasingly complex, data-oriented environments. Ennis (2011) conceptualizes critical thinking as a reasoned process encompassing interpretation, evaluation, and inference, while Facione (2015) expands this definition by incorporating perception, reflection, and deliberate decision-making as core attributes of sound reasoning.

Within the context of the Fourth Industrial Revolution, these cognitive capacities enable individuals to manage ambiguity, address uncertainty, and navigate rapid organizational and

technological transitions (Khairunnisa & Ilmi, 2020; Mabe & Bwalya, 2022). Furthermore, critical thinking contributes substantially to leadership development and decision-making in knowledge-based economies, where soft skills are increasingly regarded as essential to professional expertise (Lubinga et al., 2023).

In vocational education, however, learning practices often prioritize procedural mastery and technical skill development at the expense of reflective and analytical engagement. Such emphasis can limit learners' opportunities to critically examine real-world problems or to participate in self-directed learning. Recent studies (Ruijuan et al., 2023) emphasize that integrating collaboration and inquiry-based strategies within technical courses can enhance student motivation, engagement, and performance. Similarly, reflective learning processes have been shown to nurture autonomy and professional identity (Mohamed et al., 2022; Rokayah et al., 2023).

In this context, Project-Based Learning (PjBL) has become a significant educational approach that aligns with the goals of 21st-century learning. It encourages the enhancement of advanced thinking skills, teamwork, innovation, and communication (Rehman , 2024). Nonetheless, its application in vocational environments often faces obstacles such as limited access to technology, a lack of effective facilitation skills, and insufficient learner preparedness (Mutanga, 2024).

To address these gaps, the integration of Agile Learning principles into project-based contexts has been proposed. Originally derived from software engineering practices, Agile emphasizes iteration, collaboration, and feedback-driven improvement cycles. Recent educational adaptations (Pócsová et al., 2020; De Barros et al., 2023; Zahorodko, 2023) demonstrate that Agile-based instruction strengthens student engagement, encourages collaborative inquiry, and enhances critical reflection. This approach complements the PjBL model by fostering adaptability, iterative progress, and shared responsibility for learning outcomes.

Collectively, previous research indicates that combining Agile and PjBL principles offers a dynamic framework to cultivate critical and creative thinking while addressing the needs of vocational learners in the 21st century.

RESEARCH METHOD

This research utilized a Research and Development (R&D) approach to design, implement, and evaluate an innovative instructional framework known as Project-Based Agile Learning (PjBL–Agile), which aims to strengthen critical thinking skills among vocational high school learners. The development process followed the ADDIE framework—comprising the phases of Analysis, Design, Development, Implementation, and Evaluation—to ensure that the framework was systematically structured, empirically validated, and continuously refined through feedback. To test its effectiveness, a quasi-experimental design of the Nonequivalent Control Group type was employed, allowing direct comparison between learners who experienced the PjBL–Agile framework and those taught using traditional classroom methods.

The study was conducted at SMK Negeri 1 Donorojo and SMK Negeri Pringkuku, both located in Pacitan Regency, East Java, Indonesia. The research involved 106 learners of Grade XI majoring in Computer and Network Engineering (Teknik Komputer dan Jaringan). The

participants were split into two groups: an experimental class that applied the PjBL–Agile framework and a control class that received traditional teacher-centered instruction.

The research procedure followed five systematic stages consistent with the ADDIE framework. The analysis phase involved identifying instructional needs through classroom observations and teacher interviews, as well as analyzing learners' learning characteristics and initial critical thinking performance. During the design phase, the PjBL–Agile learning blueprint was created by integrating Agile principles—iteration, reflection, collaboration, and feedback—into the project-based learning cycle. The development phase produced validated learning materials, including a learner module, instructor guide, and critical thinking assessment instruments, which were reviewed by three experts in education, media, and the TKJ field. The average validation score exceeded 4.00 on a five-point Likert scale, indicating that the framework was highly feasible for implementation. The implementation phase was carried out over four learning sessions, during which data were collected through pretests and posttests, observation checklists, learner–teacher questionnaires, and reflective interviews. The final evaluation phase consisted of both formative and summative assessments, the former aimed at framework refinement and the latter assessing the framework's effectiveness in improving critical thinking outcomes.

Four key instruments were used in data collection: a critical thinking test (pretest–posttest) to measure improvement in reasoning ability; an observation sheet to record learner participation and collaboration; a questionnaire to capture perceptions of the learning process; and a reflective interview to gather qualitative insights into learner experiences.

Data were analyzed through a combination of quantitative and qualitative methods. Quantitative data were processed using the Normalized Gain (N-Gain) to determine the level of learning improvement and t-tests (paired and independent samples) to identify statistical differences between and within groups. Qualitative data derived from observations and interviews were analyzed thematically to interpret behavioral and contextual patterns that complemented the numerical outcomes. Together, these analyses provided a holistic understanding of how the PjBL–Agile framework enhanced the critical thinking competence of vocational learners in the context of SMK Negeri 1 Donorojo and SMK Negeri Pringkuku.

RESULT AND DISCUSSION

The comparative results between the two classes revealed a significant increase in learners' critical thinking scores. Students who participated in the **PjBL–Agile** sessions showed a mean improvement from **24.31 to 32.14**, while the control group's mean rose slightly from **25.11 to 26.23**. Paired-sample *t*-test analysis confirmed the significance of this gain ($t(69) = -12.59$, $p < 0.001$).

The **N-Gain** results indicated a medium-level improvement for the experimental group ($g = 0.499$) and a low-level improvement for the control group ($g = 0.076$), aligning with Hake's (1999) classification criteria. Independent *t*-test results further confirmed a significant difference between the two cohorts ($t(138) = 10.96$, $p < 0.001$), reinforcing the model's effectiveness in promoting higher-order thinking.

Qualitative observations supported these statistical findings. Learners in the experimental group demonstrated more active collaboration, frequent peer feedback, and deeper reflective

engagement during sprint reviews. Teachers also reported enhanced learner autonomy and responsibility in project completion. These behaviors align with previous studies that associate Agile-based learning environments with increased engagement and reflective depth (Pócsová et al., 2020; De Barros et al., 2023).

The **PjBL–Agile** approach's iterative structure allowed learners to continuously refine project outcomes through cycles of feedback and reflection, facilitating the internalization of critical thinking dispositions. This continuous loop mirrors authentic workplace processes, where adaptability and collaboration are essential.

Overall, findings from this study substantiate the pedagogical advantage of integrating Agile principles within project-based instruction for vocational education, offering an adaptive and reflective model suited for Industry 4.0 skill development.

Analysis of the pretest and posttest results revealed that students who participated in the PjBL–Agile model showed a significantly greater enhancement in critical thinking abilities compared to those in the control group. Table 1 presents the descriptive statistics for both groups.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Group	Test	N	Mean	SD
Control	Pretest	53	25.11	4.31
Control	Posttest	53	26.23	4.11
Experimental	Pretest	53	24.31	4.39
Experimental	Posttest	53	32.14	3.82

As seen in Table 1, the mean score in the experimental class rose by **7.83 points**, while the control class increased by only **1.12 points**. This pattern suggests that students engaged in PjBL–Agile learning experienced deeper conceptual and reflective growth.

To further quantify learning effectiveness, a normalized gain (N-Gain) analysis was conducted, as displayed in Table 2.

Table 2. N-Gain Analysis

Group	Mean N-Gain	Category
Control	0.076	Low
Experimental	0.499	Moderate

e N-Gain result of 0.499 in the experimental group indicates a moderate level of effectiveness, while the control group's value of 0.076 falls within the low category. According to Hake's classification, this shows that the PjBL–Agile model promotes more meaningful learning improvement compared to traditional instruction.

To test the significance of these findings, paired and independent t-tests were performed. The results are summarized in

Table 3. Summary of t-Test Results

Type of Test	Group	t(df)	p-value	Interpretation
Paired t-test (Pre–Post)	Experimental	–12.59 (52)	< 0.001	Highly significant improvement
Paired t-test (Pre–Post)	Control	–2.18 (52)	0.034	Slight improvement
Independent t-test (N-Gain)	Control vs Experimental	10.96 (104)	< 0.001	Significant difference between groups

The p-value (< 0.001) confirms that differences between groups are statistically significant. These results demonstrate that the implementation of the PjBL–Agile model positively affects students' critical thinking ability in a consistent and measurable way.

Observation and interview data provided additional insight into how the model influenced classroom dynamics. Students in the experimental group actively engaged in collaborative activities, demonstrated curiosity in exploring project challenges, and frequently reflected on their progress after each sprint cycle. Teachers noted that students were more motivated to take responsibility for their learning outcomes and worked more effectively within teams.

The iterative feedback loops within each sprint encouraged students to evaluate their strategies and modify their approaches. This process allowed them to identify misconceptions early, strengthen reasoning, and refine solutions—characteristics central to critical thinking. In contrast, students in the control group tended to rely on teacher direction, showed limited initiative, and rarely revised their work collaboratively.

CONCLUSION

This study provides empirical evidence that the Project-Based Agile Learning (PjBL–Agile) framework effectively enhances learners' critical thinking abilities in vocational education. The integration of Agile principles—iteration, reflection, collaboration, and continuous feedback—into the project-based structure successfully created a more dynamic and learner-centered learning environment. Quantitative analysis showed a substantial increase in posttest scores for the experimental group compared to the control group, supported by a moderate N-Gain value (0.499) and statistically significant differences ($p < 0.001$). These outcomes indicate that the PjBL–Agile framework fosters meaningful learning progress rather than surface-level understanding.

Qualitative outcomes further confirmed that learners engaged in the Agile-based learning cycles displayed higher motivation, stronger teamwork, and greater responsibility for their learning outcomes. The iterative feedback loops encouraged reflection and adaptive problem-solving, key aspects of critical thinking development. In contrast, the control group's progress remained limited, emphasizing the necessity of learner-centered models in vocational contexts.

Overall, the PjBL–Agile approach bridges the gap between practical skills and analytical reasoning in vocational education. It prepares learners not only to master technical competencies but also to think critically, collaborate effectively, and adapt to technological changes in the Industry 4.0 era. Future research is recommended to apply the framework across various subjects and longer implementation periods to explore its broader impact on other 21st-century skills, such as creativity, communication, and collaboration.

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