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Project-Based Practical on Students Creativity in the Control System Subject at Vocational School

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ABSTRACT

The low level of student creativity in engineering subjects is frequently attributed to monotonous instructional methods, whereas the demands of Industry 4.0 require vocational students to possess high creative competencies to manage complex control systems. This study aims to analyze the effect of project-based practicum implementation on student creativity in the Control Systems subject at Vocational School 5 Makassar. Employing a quantitative approach with a quasi-experimental pretest-posttest control group design, the research involved 44 grade XI students selected through random sampling, divided into experimental (n=23) and control (n=21) groups. Data was collected using a creativity questionnaire covering fluency, flexibility, originality, and elaboration dimensions. Statistical analysis, including Shapiro-Wilk's and Levene's tests, preceded the hypothesis testing via independent samples t-test. The findings reveal that the experimental group achieved a posttest mean score ($\bar{x}$) of 81.48, significantly outperforming the control group's score of 65.05. The t-test yielded a significant value of $p = 0.000$ ($p < 0.05$), confirming that project-based practicum acts as an effective catalyst in transforming creative potential into applicable innovative competencies. These results align with the vision of Competency-Based Training (CBT), providing a robust reference for vocational educators to implement innovative learning strategies relevant to the modern industrial landscape.

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1. INTRODUCTION

Vocational education is a strategic pillar in the national education architecture, playing a vital role in accelerating the availability of skilled, adaptive, and competent human resources (Jumiarti et al., 2025; Rande et al., 2025). Amidst the rapid dynamics of the Industrial Revolution 4.0, vocational high schools are required to produce not only graduates who master theoretical literacy but also a workforce with operational agility in applying knowledge to complex real-world work situations (Lee, 2024). However, a major challenge arises when the quality of vocational high school graduates is often perceived as not aligned with the expectations of the industrial world, which requires high levels of innovation (Kayyali, 2025; Khamdamovna, 2025). The effectiveness of vocational education depends heavily on selecting a learning paradigm relevant to the demands of 21st-century competencies, where the integration of technical hard skills and cognitive soft skills is an absolute requirement for students' future career success (Manuel, 2017; McGrath & Yamada, 2023).

Despite acknowledging the urgent need for innovation, vocational education practices continue to rely on stagnant conventional approaches. Various empirical studies reveal that one-way instructional methods tend to fail to develop higher-order thinking skills. Hazizah et al. (2023) found that learning patterns in vocational schools are still stuck in rote memorization and lecture methods, where practical activities are conducted procedurally without providing space for students to explore new ideas. This rigid learning structure positions students as passive recipients of information, which in turn hinders the internalization of deep conceptual understanding. In line with this, Zhai et al. (2024) emphasized that reliance on traditional methods results in low knowledge transfer. Students may be able to replicate laboratory work steps but often fail miserably when faced with technical scenarios that differ slightly from those in the module. This limited space for exploration systematically stifles creative thinking, even though creativity is a key element in solving unforeseen technical problems in industry.

In response to the failures of conventional methods, the modern educational paradigm has shifted radically toward an active learning approach that prioritizes student independence and emotional and intellectual engagement (Bhardwaj et al., 2025; Dada et al., 2023; Kerimbayev et al., 2023). One model that has received widespread attention is the project-based practicum (Hasan et al., 2023; Purwanti et al., 2024). Siminto et al. (2025) explain that this approach transforms the classroom into a discovery laboratory, where students engage in real-world problem-solving, system design, testing, and evaluation of results. This model is firmly rooted in constructivist theory, which believes that true knowledge cannot be transmitted but must be independently constructed by individuals through direct interaction with the environment and reflection on experiences (Ahmad, 2025; Gannar & Kilani, 2025; Putri et al., 2025). Through project activities, students engage in an intensive cycle of trial and error. Syafila and A'yun (2024) reinforce this argument by stating that through project work, students not only consume theory but also build their own cognitive structures through in-depth systems analysis and independent experimentation.

Within the spectrum of engineering education, the control systems subject occupies a crucial yet challenging position (Stoica et al., 2023). This field is a multidisciplinary integration that combines concepts from power electronics, precision mechanics, sensor technology, actuators, and microcontroller programming algorithms. The highly technical and abstract nature of this material makes it impossible to fully grasp it through verbal explanations or predetermined "cookbook" lab practices. Putri et al. (2024) suggested that project-based practicums significantly contribute to the development of students' technical character; technical obstacles in projects force students to face failure as part of the learning process. Therefore, the application of projects in control systems is not simply a teaching strategy but an essential need to bridge complex control theory with practical applications in industry.

The relevance of creativity in engineering education is further emphasized by shifting global job market needs (Cropley et al., 2015; Higuera Martínez et al., 2021). A World Economic Forum report cited by Kahar et al. (2021) lists creativity, critical thinking, and complex problem-solving as the three most vital skills for today's graduates. Industry no longer needs "human robots" capable of simply following manual instructions but rather innovative individuals capable of designing new efficiencies and implementing technical improvisations (Handayani et al., 2024). Creativity in a vocational context is not merely artistic but technical—the ability to modify systems, find more efficient programming routes, or design more ergonomic component layouts (Kovalchuk et al., 2022; Magenes et al., 2022). The job readiness of vocational high school students is largely determined by the extent to which they are accustomed to autonomous project management from school (Sudarsono et al., 2022).

Although the effectiveness of project-based learning has been widely documented, a significant research gap remains, particularly in the context of vocational secondary education in Indonesia. The novelty of this research lies in its comprehensive effort to measure the impact of project-based practicums specifically on the four pillars of students' technical creativity in the control systems subject: (1) fluency (fluency in generating design ideas), (2) flexibility (flexibility in changing technical approaches), (3) originality (uniqueness of the proposed solution), and (4) elaboration (depth of system design detail). Most previous research tends to limit itself to measuring cognitive learning outcomes or standard psychomotor skills. This research goes beyond these limitations by examining how the automated control system design process can stimulate creative potential that has been suppressed due to instructional learning patterns.

Empirical conditions at Vocational School 5 Makassar provide strong justification for conducting this research. Based on initial observations, it was found that although the school has adequate laboratory facilities, the learning process remains highly directive. Teachers provide very detailed work steps (rigid SOPs), resulting in the results of all students' practicums tending to be uniform without any innovative variation. This phenomenon of imitation without understanding results in students losing their design reasoning. When faced with independent assignments to design an automatic temperature control system or smart garden, students experience intellectual blockages and difficulty taking the first step and tend to plagiarize projects from the internet without significant modification. This indicates that students' out-of-the-box abilities have not been optimally developed, even though the potential for exploration in topics such as sensor-based lighting control systems or security alarms is vast if given the right stimulus.

To address this decline in creativity, this study implemented a quasi-experimental approach by intervening in the experimental class through project-based practicums. In this model, the teacher's role radically transforms from being an information authority to being a facilitator and mentor who guides without dictating (Basuki & Hidayah, 2025). We expect a significant surge in students' creative competencies by providing general directions and allowing them to design the details of their own solutions. This study aims to provide strong empirical evidence regarding the effectiveness of project-based practicums in fostering innovative solutions to technical challenges. The results are expected to provide theoretical contributions to the development of engineering pedagogy and practical benefits for stakeholders in designing vocational high school curricula that are truly aligned with the needs of 21st-century global competencies.

2. METHOD

This study employed a quantitative approach with a quasi-experimental design using a pretest-posttest control group design. This design aims to accurately identify and analyze causal relationships between independent and dependent variables. The data obtained were then tested through objective inferential statistical analysis to ensure the validity of the findings. The structure and details of the research design are presented in Table 1 below.

Table 1. Pretest-Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experiment (E)	O1	X	O2
Control (C)	O3	−	O4

This research was conducted at Vocational School 5 Makassar, located in Makassar City, South Sulawesi Province, with implementation scheduled for the even semester of the 2025/2026 academic year. The study population included all 11th-grade students studying control systems at the school. Random sampling was used to determine the experimental and control groups. This resulted in a total sample of 44 students, consisting of 23 respondents in the experimental group and 21 respondents in the control group.

This research framework centers the analysis on two main functionally interrelated variables. The independent variable (X) is Project-Based Practicum, a learning method that integrates independent technical exploration with the completion of real-world tasks in the field of control systems. Meanwhile, the dependent variable (Y) is student creativity, defined as the manifestation of cognitive and affective abilities in generating original ideas, modifying systems, and developing innovative solutions to various technical problems encountered.

Primary data in this study was collected through a creativity questionnaire instrument using a four-point Likert scale to eliminate the tendency for bias in the mean. This instrument consists of 25 items developed based on Torrance's four dimensions of creativity: fluency (fluency in generating ideas), flexibility (variety of problem-solving perspectives), originality (uniqueness of technical ideas), and elaboration (ability to detail system design concepts). Before implementation, the instrument underwent expert judgment validation and field trials to ensure its validity and reliability met the required psychometric standards. Additionally, secondary data was obtained through school documentation, including student demographic data and learning materials.

The research was conducted systematically through three main integrated phases. The preparation phase began with obtaining institutional permits, initial observations, developing Learning Implementation Tools (Modules), and standardizing the instrument. Next, in the implementation phase, a pretest was administered to both groups to measure the baseline creativity, followed by treatment administration to the experimental group over a specific period, and concluding with a posttest using identical instruments to measure post-intervention changes. This entire series concluded with the analysis phase, where the measurement data were thoroughly processed to draw valid conclusions based on the research hypothesis.

Data analysis was conducted using two main statistical techniques to provide a comprehensive picture. Descriptive statistics were used to present the data distribution through the calculation of the mean ($\bar{x}$), standard deviation (s), and variance (s^2). Meanwhile, inferential statistics were applied to test the significance of the research results. Prior to hypothesis testing, prerequisite analysis tests were conducted, including the Shapiro-Wilk Normality Test to ensure data distribution and Levene's Homogeneity Test to ensure equality of variance between groups. The final stage of analysis used an independent samples t-test to test the significance of differences in mean creativity between the experimental and control groups.

3. RESULTS AND DISCUSSION

Results

Descriptive Analysis

Presenting data through comparative tables allows researchers to comprehensively identify trends in creativity change, evaluate consistency across indicators, and systematically present information for easy interpretation. In this context, the tables serve as analytical tools, providing a deeper understanding of the significance of the intervention's impact on each research group. Through structured data visualization, researchers can objectively map the effectiveness of the treatment and strengthen arguments in the scientific decision-making process.

Prior to administering the treatment, baseline measurements were conducted via pretests (O_1 and O_3) in the experimental and control groups to identify and compare students' initial creativity profiles. This procedure is crucial for verifying the homogeneity of the respondents' baseline conditions, which also serves to strengthen the internal validity of the study before the intervention is implemented. By ensuring an equal starting point, any significant differences that emerge in the final stage can be appropriately attributed to the learning intervention.

Table 2. Description of Pretest Data for Experimental and Control Groups

Group	N	Mean	Standard Deviation	Minimum Score	Maximum Score
Experiment (O1)	23	62,35	5,12	52	73
Control (O3)	21	61,90	5,45	50	72

The data presented in Table 2 shows that the average pretest score for the experimental group was 62.35, while the control group scored 61.90. This very small difference indicates that the margin of difference between the two groups was not significant at the initial stage. The consistency of the data distribution pattern is also observed through similar score ranges and standard deviations, indicating that the distribution of students' creativity abilities in both classes had identical characteristics before the intervention.

Statistically, this finding confirms that both groups had equivalent initial levels of creativity before the start of the experimental treatment. This equivalence of initial conditions is a crucial prerequisite for ensuring the internal validity of the study. Thus, these measurement results provide a strong foundation for subsequent testing, allowing changes that emerge after the intervention to be validly attributed to the impact of the applied learning method, rather than to differences in the subjects' initial abilities.

Table 3. Description of Posttest Data for Experimental and Control Groups

Group	N	Mean	Standard Deviation	Minimum Score	Maximum Score
Experiment (O2)	23	81,48	4,87	72	90
Control (O4)	21	65,05	5,20	55	76

The data presented in Table 3 shows a trend of increasing scores in both research groups, but the magnitude was disproportionate. The experimental group showed significant improvement with an average score of 81.48, while the control group experienced only a marginal increase with an average score of 65.05. The mean difference of 16.43 points between the two groups provides a strong quantitative indication of the effectiveness of the treatment provided during the learning process.

This contrasting difference in achievement confirms that the intervention in the experimental group had a significantly more significant impact on the development of student creativity than the conventional method in the control group. This striking difference in results confirms that the project-based practicum method can stimulate the creativity dimension more optimally. A visual comparison of the distribution of students' pretest and posttest scores for the two groups is detailed in Figure 1.

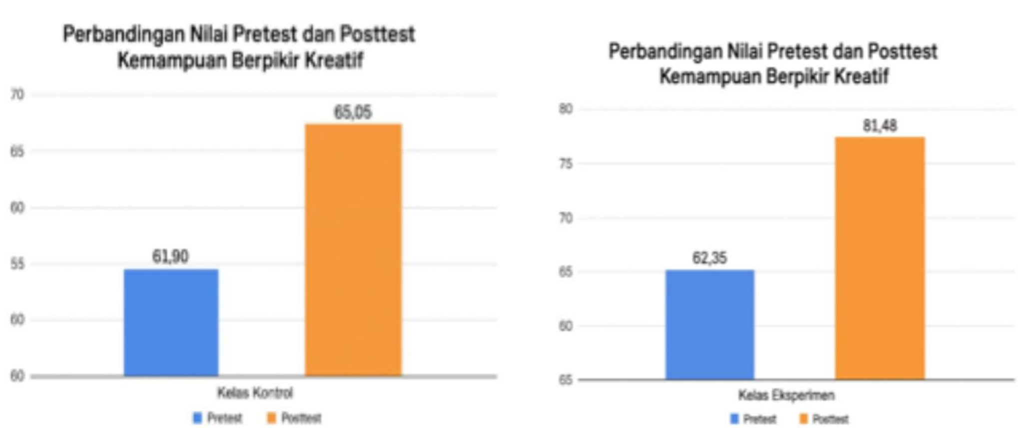

Figure 1. Improvement in Learning Outcomes

The test results in Figure 1 show that the control group, which underwent conventional learning, demonstrated very limited growth in creativity. The average pretest score of 61.90 indicated that students' creative thinking skills were initially moderate and had not yet developed optimally. After the learning process concluded, the posttest scores only increased to 65.05, representing a marginal increase of 3.15 points. These data confirm that the traditional approach has a very limited impact in significantly stimulating aspects of student creativity.

In contrast, the experimental group, which received the project-based learning intervention, demonstrated substantial achievement transformation. Although the initial pretest score of 62.35 indicated equivalence with the control group before the intervention, the posttest score jumped dramatically to 81.48 after the implementation of the project-based practicum method, representing a 19.13-point increase. This increase in the experimental group, which was more than sixfold greater than the control group, provides strong empirical evidence that integrating projects into practicum activities can explore students' creative potential far more effectively than conventional instructional methods.

Table 4. Results of the Shapiro-Wilk Data Normality Test

Group	Measurement	Statistics	Sig.
Eksperimen	Pretest (O1)	0,965	0,581
	Posttest (O2)	0,971	0,752
Kontrol	Pretest (O3)	0,959	0,423
	Posttest (O4)	0,962	0,512

The results of the normality test for the distribution of pretest and posttest data from both research groups are summarized in Table 4. Based on the Shapiro-Wilk analysis, the experimental group demonstrated a significance value (p) of 0.581 in the pretest phase, increasing to 0.752 in the posttest phase, with statistical coefficients of 0.965 and 0.971, respectively. These figures indicate that the data distribution in the treatment group conformed very well to the normal curve.

Meanwhile, in the control group, the significance values obtained were 0.423 for the pretest and 0.512 for the posttest, with statistical coefficients of 0.959 and 0.962, respectively. Considering that all significance values exceeded the alpha threshold of 0.05, it can be concluded that the student creativity data in both groups, both before and after the intervention, were normally distributed. The consistency of the statistical coefficients in the range of 0.959 to 0.971 strengthens the indication that the data convincingly fulfills the assumption of normal distribution, so it is worth proceeding to the parametric statistical analysis stage.

Table 5. Results of Homogeneity Test

Levene's Test	df1	df2	Sig.
0,542	1	42	0,465

Building upon the results of the homogeneity of variance test presented in Table 5, the Levene's statistic value was 0.542 with $df_1 = 1$ and $df_2 = 42$ degrees of freedom. This analysis yielded a significance value (p) of 0.465. Because this significance value is greater than the alpha level of significance of 0.05 ($p > 0.05$), it can be concluded that the variance of the posttest data between the experimental and control groups is homogeneous. Meeting this homogeneity assumption ensures that the differences in the results truly represent the impact of the treatment, not the result of unequal population variances.

After all analysis prerequisites have been met—from the preparation stage, data collection, to normality and homogeneity tests—the next stage is hypothesis testing to answer the research problem formulation. The results of this hypothesis testing will serve as an empirical basis for proving the effect of the intervention, which will be further comprehensively analyzed in the discussion section to provide context and meaning to the statistical findings.

Table 6. Results of the Independent Samples t-Test on Posttest Data

T-Test	**t**	**df**	**Sig. (2-tailed)**
Equal variances assumed	10,458	42	0,000

Based on the analysis results shown in Table 6, a two-tailed significance value of 0.000 was obtained. Statistically, a p-value of 0.000 indicates that the probability of a score difference of 16.43 points (or more) occurring by chance is close to 0%, assuming the null hypothesis (H_0) is true. This finding indicates a significant disparity between the experimental and control groups, exceeding random data fluctuations in the sample distribution.

Given that this significance value is much smaller than the established alpha threshold (alpha = 0.05), there is a very strong statistical basis for rejecting H_0 and accepting H_a. Therefore, it can be confidently concluded that the implementation of project-based practicums significantly increased student creativity in the Control Systems subject at Vocational School 5 Makassar. This finding provides robust quantitative confirmation of the research problem formulation and demonstrates that the intervention has a substantial educational impact.

Discussion

The statistical test results, which showed rejection of H_0 with a significance value of $p < 0.05$ ($p = 0.000$), are not merely numbers, but rather a quantitative representation of a fundamental transformation in students' creative thinking abilities. The striking difference in mean scores between the experimental group ($\bar{x}$= 81.48) and the control group ($\bar{x}$= 65.05) confirms that the implementation of project-based practicums has a significant impact on student creativity in the Control Systems subject at Vocational School 5 Makassar. This finding aligns with Vygotsky's social constructivism theory, which emphasizes that higher-order cognitive processes, including creativity, develop optimally when students are actively involved in solving complex, authentic problems (Zajda, 2021).

Empirically, the results of this study reinforce previous studies conducted by Wang et al. (2025), which demonstrated that project-based learning environments can stimulate students' fluency and originality through open-ended technical exploration. In the context of vocational education, the integration of projects into practical activities enables students to not only passively understand control theory but also synthesize ideas to generate innovative solutions to real-world problems. Thus, these findings provide profound theoretical and practical implications, positioning project-based practical work as a key catalyst in bridging the gap between students' technical competence and innovative capacity in the modern industrial era.

Furthermore, the findings of this study align with those of Siminto et al. (2025), Syafila and A'yun (2024), which emphasized that project-based learning places students at the center of activities throughout the cycle of real-world problem-solving, system design, and project evaluation. This consistency of results strengthens the argument that an active approach allows for deeper internalization of knowledge through trial and error and technical experimentation (Tönnsen, 2021). The experimental group's success in achieving significant score improvements represents a paradigm shift consistent with constructivist theory. Through direct experience and reflection on learning outcomes, project-based practicums have been shown to successfully transform students' academic identities from merely understanding concepts to creative individuals competent in producing real-world work.

Furthermore, the results of this study confirm Aini et al.'s (2023) criticism of the limitations of conventional learning models in vocational schools, which are still dominated by lectures and rigid procedural practices. The observed stagnation in creativity in the control group demonstrates that a theoretical approach without room for idea exploration tends to result in shallow understanding. This aligns with Lee (2018) view regarding the low level of knowledge transfer and the emergence of an awareness gap, where students may recognize the concept of creativity but lack the capacity to apply it. Thus, the difference in achievement between the two groups confirms that without opportunities for exploratory practice, students' creative potential will remain hampered by traditional instructional constraints.

The significant influence of project-based practicums on student creativity is rooted in a systematic working mechanism that simultaneously hones the pillars of creativity. Fluency is developed through the presentation of open-ended problems that push students beyond the single-solution paradigm. Unlike conventional procedural practicums, project-based instruction gives students the freedom to brainstorm and generate various alternative technical solutions. This process directly trains students' ability to generate ideas in large quantities—a core competency in engineering design that aligns with the findings of Dilekçi and Karatay (2023), Hasbi et al. (2022) and Muzaini et al. (2021) regarding the urgency of creative thinking as a key skill in the 21st century.

Furthermore, the dimensions of flexibility and originality are developed through the trial and error experience and freedom of choice inherent in project work. When facing technical obstacles such as sensor failures or errors in program code, students are required to adapt by seeking alternative strategies rather than simply relying on manuals. This adaptability is essential in the dynamic world of technology, as emphasized by Hasbi et al. (2025), Liu and Wan (2024). On the other hand, the freedom to design features—such as IoT integration or power efficiency optimization—encourages the creation of unique and innovative work. This learning model implicitly values originality, is a crucial element in developing an individual's creative potential.

Finally, the elaboration aspect is deepened through consideration of real-world constraints, forcing students to produce functional and reliable systems. Students are required to go beyond conceptual schemes and also consider detailed technical aspects such as cost, power consumption, and system reliability. This process transforms abstract ideas into concrete, functional designs. Consistent with Putri et al.'s (2024) opinion, working on these projects, which involve various technical obstacles, not only hones analytical skills but also shapes students' character, fostering perseverance and resilience in solving complex problems.

Theoretically, the effectiveness of project-based practicums in escalating student creativity aligns with Albert Bandura's self-efficacy theory, particularly the mastery experience dimension (Schunk & DiBenedetto, 2023). As the most dominant source of self-efficacy, mastery experience in project work provides concrete evidence of competence when students successfully complete complex technical challenges. Successfully programming a control system until it functions precisely provides far more powerful empirical validation than mere verbal praise or theoretical explanations. This fundamentally transforms students' self-perceptions from "quite creative" to "highly creative and competent," which in turn strengthens their confidence in facing future engineering challenges.

These findings also reinforce the constructivist paradigm in vocational education, where knowledge is actively constructed through interactions with authentic learning environments. As Aini (2021) explains, the systematic trial-and-error process of designing and testing control systems not only yields in-depth understanding but also fosters students' perseverance and mental toughness. This shift in methodology demands a redefinition of the educator's role. According to Basuki and Hidayah (2025), teachers now function as facilitators and mentors, providing strategic guidance without limiting students' exploration. This shift in role creates a dynamic learning ecosystem and encourages more meaningful educational interactions, where students have full autonomy in developing innovative solutions to the technical problems they face.

4. CONCLUSION

The implementation of project-based practicums significantly increased student creativity in the Control Systems subject at Vocational School 5 Makassar. This conclusion is empirically supported by the results of an Independent Samples t-test, which yielded a significance value of $p = 0.000$ ($p < 0.05$), with a substantial difference in mean scores between the experimental group ($\bar{x} = 81.48$) and the control group ($\bar{x} = 65.05$). These findings demonstrate that the project-based practicum method acts as an effective catalyst for transformation in converting students' creative potential into applicable innovative competencies, aligning with the school's vision of providing Competency-Based Training (CBT) to produce competitive graduates in the Industry 4.0 era.

As a practical recommendation, educational institutions are advised to consistently integrate this learning model into productive curricula by providing open-ended system design challenges, providing laboratory facilities that support independent exploration, and equipping educators with skills as project facilitators to ensure the sustainable development of a culture of innovation within the school environment.

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