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Integrating Python Programming into Contextual Project Learning to Foster University Students' Learning Outcomes

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ABSTRACT

Improving university students' learning outcomes in mathematics requires instructional approaches that promote active engagement, meaningful learning, and the integration of digital technologies. Python programming has recently gained attention as an educational tool for supporting computational problem-solving and conceptual understanding. This study aimed to examine the effect of integrating Python programming into contextual project learning on university students' learning outcomes. A quasi-experimental research design employing a non-equivalent control group was conducted involving 58 undergraduate students enrolled in the Basic Concepts of Mathematics course at Universitas Muhammadiyah Muara Bungo, Indonesia. The experimental group consisted of 30 students who participated in Python-integrated contextual project learning, while the control group comprised 28 students who received conventional instruction. Students' learning outcomes were measured using pretest and posttest achievement tests. The data were analyzed using descriptive statistics, the Shapiro-Wilk normality test, Levene's homogeneity test, and the Mann-Whitney U test because the posttest scores were not normally distributed. The findings indicated that there was no significant difference in students' initial abilities before the intervention, whereas the posttest results revealed a significant difference between the experimental and control groups in favor of the experimental group ($p < .05$). The integration of Python programming into contextual project learning enabled students to engage more actively in contextual problem-solving, computational exploration, and collaborative project activities, resulting in improved learning outcomes. These findings suggest that integrating Python programming into contextual project learning provides an effective instructional approach for enhancing university students' mathematics learning outcomes in higher education.

Keywords: Contextual Project Learning; Python Programming; Learning Outcomes; Mathematics Education; Quasi-Experimental Study

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INTRODUCTION

Improving learning outcomes has become one of the primary objectives of higher education, particularly in mathematics education, where students are expected not only to master theoretical concepts but also to develop problem-solving abilities, critical reasoning, and the capacity to apply mathematical knowledge in authentic situations (Sofroniou et al., 2025; Sormunen et al., 2022). Learning outcomes represent measurable evidence of students' cognitive achievement after participating in instructional activities and serve as an important indicator of instructional quality. Accordingly, higher education institutions are increasingly encouraged to implement student-centered pedagogical approaches that actively engage learners in constructing knowledge, collaborating with peers, and applying concepts to solve authentic problems rather than relying on passive information transfer (Sormunen et al., 2022). This educational transformation is consistent with contemporary constructivist perspectives, which emphasize that meaningful learning occurs when students actively build understanding through experience, inquiry, and reflection. Furthermore, the rapid advancement of digital technology has reinforced the necessity of integrating computational tools into mathematics instruction to enhance conceptual understanding, increase student engagement, and prepare graduates with competencies required in the twenty-first century (Budiarti & James, 2025; Sofroniou et al., 2025). Recent evidence also indicates that technology-supported mathematics learning environments contribute positively to students' academic achievement when digital tools are integrated with appropriate pedagogical strategies rather than being used solely as instructional media (Amaludin et al., 2025; Geleto Wariyo et al., 2026; A. Susanti et al., 2026).

Despite ongoing efforts to improve mathematics instruction, university students' learning outcomes remain unsatisfactory because teaching often emphasizes procedural calculations rather than conceptual understanding and active learning (Mangarin & Caballes, 2024; Roca-Hurtuna et al., 2021). Consequently, students tend to memorize formulas without understanding their real-world applications, limiting their engagement and academic achievement (Hwang & Tu, 2021; OECD, 2024). Since conventional teacher-centered instruction is less effective in promoting higher-order thinking (Darling-Hammond et al., 2020; Lo & Hew, 2017). more authentic and student-centered instructional approaches are needed to improve learning outcomes.

Recent educational reforms have emphasized student-centered learning that connects mathematical concepts with authentic experiences to promote deeper understanding and improved learning outcomes (OECD, 2023; UNESCO, 2023). Consistent with constructivist learning theory, meaningful learning occurs when students actively construct knowledge through interaction and experience (Schukajlow et al., 2023). In mathematics education, contextual learning enables students to relate abstract concepts to real-life situations, thereby enhancing conceptual understanding, engageme;nt, and academic achievement (Cruz Neri & Retelsdorf, 2022; Geleto Wariyo et al., 2026; Kisworo et al., 2021). Recent evidence further confirms that contextual learning has a positive effect on mathematics achievement and student engagement across educational levels (Geleto Wariyo et al., 2026).

Among student-centered instructional approaches, Project-Based Learning (PBL) has gained considerable attention because it engages students in investigating authentic problems, collaborating with peers, and developing meaningful learning products, thereby enhancing conceptual understanding and academic achievement (Barragán Moreno & Aya Corredor, 2026; Lethulur et al., 2025). However, projects alone do not automatically ensure meaningful learning outcomes. Recent studies emphasize that project activities should be grounded in authentic contexts to maximize student engagement, knowledge transfer, and conceptual understanding (Audra Pramitha Muslim et al., 2024; M. Susanti et al., 2023). Therefore, integrating contextual learning with PBL offers a promising approach to creating meaningful mathematics learning experiences and improving university students' learning outcomes.

Advances in digital technology have created new opportunities for mathematics education by supporting computational exploration, visualization, and interactive learning (Goldenberg et al., 2021). Among various programming languages, Python has become widely adopted because of its simple syntax, rich scientific libraries, and ability to represent abstract mathematical concepts through computation and visualization (Kaufmann & Stenseth, 2021). Consequently, Python serves not only as a programming language but also as an effective cognitive tool for supporting meaningful mathematics learning.

In particular, Python enables students to model mathematical concepts, visualize abstract ideas, and verify solutions through computational exploration, thereby facilitating deeper mathematical understanding (Goldenberg et al., 2021; Kaufmann & Stenseth, 2021). Furthermore, integrating Python into contextual mathematical tasks promotes meaningful learning and increases student engagement by connecting computational processes with authentic real-world situations (Hsiao et al., 2023). These findings suggest that Python functions not only as a programming language but also as an effective instructional tool for technology-enhanced mathematics learning.

Although contextual learning, Project-Based Learning (PBL), and programming-supported instruction have each demonstrated positive effects on students' learning, they have largely been examined as separate instructional approaches. Likewise, PBL has consistently improved students' engagement and academic achievement, yet its integration with digital technologies in mathematics education remains limited (Guo et al., 2020). Moreover, most studies involving Python programming have been conducted in computer science, than mathematics education for prospective elementary school teachers (Hsiao et al., 2023; Kaufmann & Stenseth, 2021). Recent reviews also highlight the need for instructional models that integrate contextual learning, project-based learning, and programming within a unified pedagogical framework (Hwang & Tu, 2021). Therefore, this study addresses this gap by investigating the integration of Python programming into contextual project learning to improve university students' learning outcomes..

Based on these considerations, this study investigates the integration of Python programming into contextual project learning to improve the learning outcomes of prospective elementary school teachers. Previous studies have shown that contextual project-based learning enhances mathematics achievement (Rasmini & Antara, 2023). while Project-Based Learning integrated with Python programming promotes student engagement and academic performance (Kholijah et al., 2023). More recently, (Karnando et al., 2024) reported that integrating Python programming into Project-Based Learning created a more interactive and meaningful learning environment that supported students' learning achievement. Similarly, (Yao et al., 2026) Likewise, technology-supported project-based mathematics learning has been found to improve students' conceptual understanding and learning achievement. Therefore, this study is expected to contribute empirical evidence regarding the effectiveness of integrating Python programming into contextual project learning while providing practical recommendations for mathematics lecturers seeking to implement technology-supported instruction in higher education.

Contextual learning has become an important approach in mathematics education because it connects mathematical concepts with authentic real-life situations. This approach aligns with constructivist learning theory, which emphasizes that knowledge is actively constructed through meaningful experiences and interactions with the learning environment. Recent studies have shown that contextual learning supported by authentic projects enhances students’ mathematics achievement, motivation, and conceptual understanding (Rasmini & Antara, 2023). Furthermore, technology-supported and project-oriented contextual learning has been reported to create meaningful learning environments that improve mathematical achievement and higher-order thinking skills (Amaludin et al., 2025; Sofroniou et al., 2025; Yao et al., 2026).

Project-based learning strengthens contextual learning by involving students in authentic investigations, collaboration, and reflection to connect mathematical concepts with real-world problems. According to Rehman et al., (2024), project-based learning promotes active engagement and higher-order thinking skills in mathematics education. Furthermore, (Yao et al., 2026), found that technology-supported project-based learning improves conceptual understanding and creativity, while Cruz et al., (2022), confirmed its positive effects on mathematics achievement, problem-solving, and motivation.

The integration of contextual learning and project-based learning provides a more meaningful mathematics learning experience by connecting real-world contexts with authentic problem-solving activities. Contextual learning gives relevance to project tasks, while project-based learning enables students to apply mathematical concepts through investigation, collaboration, and reflection. Recent studies have reported that project-based learning supported by authentic contexts significantly improves students' engagement, conceptual understanding, collaboration, and mathematics achievement across different educational settings (Cruz et al., 2022; Rehman et al., 2024). Likewise, project-oriented learning integrated with meaningful real-world tasks has been found to strengthen students' ability to apply mathematical knowledge in authentic situations while promoting active participation and long-term learning (Jiménez-Gaona & Vivanco-Galván, 2024; Pomboza Floril et al., 2026). Furthermore, continuous interaction among students, lecturers, and learning resources within contextual project activities creates an active learning environment that facilitates meaningful knowledge construction and sustained academic development.

Digital technology, particularly Python programming, provides new opportunities to enhance contextual project learning in mathematics. Python's simple syntax and flexibility support mathematical modelling, visualization, and exploration of concepts, making it suitable for educational contexts. According to Dilling et al., (2024) and Weigand et al., (2024), Python integration enhances conceptual understanding and engagement. Recent studies have also shown that integrating Python into mathematics instruction enhances students' learning outcomes and motivation by providing dynamic representations of mathematical concepts and opportunities for active exploration, while Pinargote-Zambrano et al., (2024) found that it improves students' learning outcomes and motivation.

In mathematics education, Python serves not merely as a programming language but as a pedagogical tool that enables students to explore mathematical concepts through dynamic investigation and interactive problse solving. Through programming activities, students can represent mathematical relationships, perform numerical computations efficiently, visualize functions and graphs, simulate mathematical models, and verify analytical solutions. These learning experiences encourage students to actively construct mathematical knowledge rather than relying solely on procedural calculations. By providing immediate feedback on computational results, Python allows students to identify errors, refine solution strategies, and evaluate the validity of their mathematical reasoning throughout the learning process. Such opportunities for exploration and reflection support inquiry-based learning and promote deeper conceptual understanding of mathematics (Goldenberg & Carter, 2021; Weigand et al., 2024). Furthermore, recent studies have reported that integrating Python into mathematics instruction enhances students' engagement, mathematical modelling skills, and problem-solving performance by enabling interactive exploration of mathematical concepts in authentic learning environments (Pinargote-Zambrano et al., 2024; Rais & Zhao, 2024).

The integration of Python programming into contextual project learning enhances mathematics education by supporting visualization, modelling, and problem-solving. Programming activities help students understand abstract concepts through interactive representations (Weigand et al., 2024). Second, contextual project activities provide authentic learning situations that require students to integrate mathematical reasoning with programming skills to solve real-world problems, thereby promoting meaningful knowledge construction and improving learning outcomes (Jiménez-Gaona & Vivanco-Galván, 2024). Third, collaborative programming activities encourage communication, peer learning, and collective problem-solving, allowing students to exchange ideas, evaluate alternative solution strategies, and develop deeper mathematical understanding (Karnando et al., 2024). Furthermore, recent bibliometric evidence indicates that integrating technology into project-based mathematics learning has become an increasingly prominent research direction because it effectively supports active learning, conceptual understanding, and student engagement (M. Susanti et al., 2023). Finally, computational visualization enables students to interpret mathematical relationships more accurately than traditional symbolic representations alone, supporting conceptual development and increasing engagement during mathematics learning (Hadi et al., 2026).

Despite increasing research on contextual learning, project-based learning, and programming-assisted instruction, studies integrating these approaches in university mathematics education remain limited. Research on project-based learning has mainly focused on achievement, problem-solving, and critical thinking, with less attention to contextual learning and programming integration (Barragán Moreno & Aya Corredor, 2026; Lasso Cardona, 2023). Reviews also emphasize the need for technology-enhanced learning models that combine digital tools with authentic pedagogical approaches (Weigand et al., 2024).

Furthermore, technology-supported project learning offers opportunities for developing context-based computational learning in mathematics education (Yani et al., 2026). Thus, further research is needed on Python-based contextual projects, particularly for prospective elementary school teachers.

Integrating Python programming into contextual project learning offers an innovative approach to university mathematics education by linking mathematical concepts to authentic contexts while promoting computational exploration. This approach has been shown to strengthen conceptual understanding, increase student engagement, and improve learning outcomes through meaningful and collaborative learning experiences.

Integrating Python programming into contextual project learning offers an innovative approach to university mathematics education by linking mathematical concepts to authentic contexts while promoting computational exploration. This approach has been shown to strengthen conceptual understanding, increase student engagement, and improve learning outcomes through meaningful and collaborative learning experiences (Rehman et al., 2024). Recent research emphasizes using digital technologies as pedagogical tools to promote mathematical modelling, conceptual exploration, and active knowledge construction, (Weigand et al., 2024). Recent evidence from higher education further suggests that project-based pedagogical practices supported by digital learning environments contribute significantly to the development of transversal competencies, including collaboration, communication, problem-solving, and academic performance (Guerra-Macías & Tobón, 2025). These findings indicate that integrating Python programming into contextual project learning can support not only students' mathematics learning outcomes but also the broader competencies required in technology-rich educational and professional environments.

Twenty-first-century mathematics education emphasizes authentic, student-centered learning supported by digital technologies. Authentic learning environments help students connect mathematical concepts with real-world contexts, improving conceptual understanding and learning outcomes, (Kholijah et al., 2023; Rasmini & Antara, 2023). Likewise, project-based learning has consistently been identified as an effective instructional approach for promoting students' engagement, collaboration, and academic performance because it encourages active participation in solving authentic problems rather than relying on passive knowledge acquisition (Cruz et al., 2022). Furthermore, recent reviews of mathematics education have emphasized that integrating digital technologies with student-centered pedagogies provides opportunities to create more interactive, meaningful, and learner-centered mathematics classrooms that better prepare students for the demands of contemporary higher education (Guerra-Macías & Tobón, 2025; Weigand et al., 2024).

Recent advances in educational technology have promoted the use of Python programming in mathematics education. Its simple syntax and computational capabilities support mathematical exploration, modelling, and visualization, while enhancing student engagement, conceptual understanding, and learning outcomes, (Rais & Zhao, 2024). Furthermore, current research emphasizes that digital technologies and programming environments facilitate mathematical modelling, visualization, and inquiry-based learning, enabling students to develop deeper conceptual understanding through interactive learning experiences (Dilling et al., 2024; Engelbrecht & Borba, 2024). Consequently, programming activities have increasingly been incorporated into mathematics education as an effective means of enriching students' mathematical learning experiences and supporting technology-enhanced pedagogy.

Despite these findings, existing research has largely examined contextual learning, project-based learning, and programming-supported learning separately, with limited attention to their integrated implementation in mathematics education, (Cruz et al., 2022; Lasso Cardona, 2023). Similarly, reviews of digital mathematics education have highlighted the rapid expansion of technology-enhanced learning but have emphasized the need for instructional models that meaningfully combine pedagogical approaches with computational tools to support mathematics learning (Engelbrecht & Borba, 2024; Weigand et al., 2024). Furthermore, studies involving Python programming have predominantly examined programming education, computational skills, rather than university mathematics learning outcomes (Munthe & Naalsund, 2024). Consequently, empirical evidence explaining how Python programming can be systematically embedded into contextual project learning to improve mathematics learning outcomes in higher education remains limited.

Moreover, most previous studies have focused on primary and secondary education, with limited research involving prospective elementary school teachers, despite the need for technology-enhanced learning that strengthens both mathematical and pedagogical competencies, (Heine et al., 2024; Rohmanurmeta et al., 2024). Furthermore, evidence indicates that many prospective elementary school teachers still demonstrate limited levels of digital literacy and technology integration skills, highlighting the need for innovative instructional models within teacher education programs (Maghfiroh et al., 2024). However, empirical evidence regarding the implementation of Python-integrated contextual project learning in mathematics teacher education remains scarce, indicating the necessity for further investigation.

Furthermore, many technology-supported mathematics studies prioritize cognitive outcomes without integrating authentic contextual projects, highlighting the need to combine contextual learning with computational tools that support mathematical modelling, visualization, and conceptual understanding, (Engelbrecht & Borba, 2024; Maghfiroh et al., 2024; Weigand et al., 2024). Therefore, integrating Python programming into contextual project learning offers considerable potential to bridge this gap by combining authentic mathematical contexts with computational exploration, enabling students to construct mathematical understanding through meaningful project activities supported by digital technology.

Based on these limitations, this study offers several novel contributions. First, it integrates Python programming into contextual project learning as a unified instructional approach rather than treating programming and contextual learning as separate educational components. Second, the study applies this integrated approach in undergraduate mathematics education for prospective elementary school teachers, a context that has received relatively little attention in previous studies. Third, the research evaluates students' learning outcomes through authentic mathematical projects requiring computational representation, collaborative investigation, and contextual problem-solving. These contributions are expected to enrich the literature on technology-enhanced mathematics education while providing practical guidance for lecturers seeking to integrate programming into university mathematics instruction.

Accordingly, the purpose of this study is to examine the implementation of Python programming integrated into contextual project learning and to investigate its effect on university students' mathematics learning outcomes. Specifically, the study addresses the following research question: Does integrating Python programming into contextual project learning significantly improve university students' learning outcomes compared with conventional mathematics instruction? Answering this question is expected to provide empirical evidence supporting the integration of computational tools into contextual mathematics learning and contribute to the advancement of innovative instructional practices in higher education.

METHOD

This study employed a quasi-experimental design. This design was chosen because the researcher did not form new classes but used existing classes. The research design was a pretest-posttest non-equivalent group design (Sugiyono, 2019). The design of the study is presented in the following table:

Kelompok	Pretest	Perlakuan	Posttest
E	O1	X1	O2
K	O1	X2	O2

Description:
E is the experimental group
K is the control group
O1 is the pretest

O2 is the posttest

X1 is Contextual Project Learning using Python

X2 is conventional learning

The participants consisted of 58 second-year students enrolled in the Primary School Teacher Education (PGSD) Program at Universitas Muhammadiyah Muara Bungo. Cluster random sampling was employed because the existing classes could not be reorganized. Two intact classes with comparable academic characteristics were randomly assigned as the experimental group (n = 30) and the control group (n = 28). The test instrument used to measure students' mathematical creative thinking skills consisted of essay questions developed based on indicators aligned with each learning outcome.

The pre-treatment analysis was conducted to examine the equivalence of students' initial conditions in terms of learning outcomes before the implementation of the instructional intervention. The results of this analysis were used to determine the appropriate statistical procedure for hypothesis testing. Since the normality test indicated that the pretest scores were not normally distributed, a non-parametric Mann-Whitney U test was employed to compare the initial learning outcomes between the experimental and control groups. The hypotheses tested were

H_{01}: There is no difference in students' initial abilities between the two groups in terms of mathematical learning outcome.

H_{a1}: There is a difference in students' initial abilities between the two groups in terms of mathematical learning outcome.

The calculation was performed using SPSS 26.0 with a significance level of 5%. The decision rule is that H_{01} is rejected if the significance value is less than 0.05.

Before analysis, the assumptions of normality.

Normality Test

The normality test was conducted to determine whether the students' mathematical creative thinking data were normally distributed. This test was applied to both experimental and control classes before and after treatment. In this study, the Shapiro-Wilk test was used because the sample size was less than 50. The data are considered normally distributed if the significance value (Sig.) is greater than 0.05, using SPSS 26.0.

Post-Treatment Analysis

After conducting prerequisite tests, including normality and homogeneity tests, it was found that the pretest data were normally distributed and homogeneous, while the posttest data were not normally distributed. Therefore, the initial equivalence analysis was conducted using an independent sample t-test, while the post-treatment difference analysis was carried out using the nonparametric Mann-Whitney U test with the assistance of IBM SPSS Statistics 26.0.

The effectiveness analysis was based on posttest results to compare the Contextual Project Learning with Python class and the conventional learning class. Since the data were not normally distributed, the Mann-Whitney U test was used with the decision rule that a significance value of < 0.05 indicates a significant difference, while a value > 0.05 indicates no significant difference. The effectiveness of the learning approach was also determined based on the mean rank value, where a higher mean rank indicates a more effective approach in improving students' mathematical creative thinking skills.

RESULT AND DISCUSSION

Results

Descriptive Statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Nilai Pretest	58	10,00	60,00	36,9310	13,35463
Nilai Posttest	58	30,00	90,00	61,2414	13,70403
Valid N (listwise)	58				

The table presents the descriptive statistics of students' learning outcomes before and after the implementation of the learning intervention. A total of 58 students participated in the study. The pretest scores ranged from 10.00 to 60.00, with a mean score of 36.93 (SD = 13.35), indicating that students' initial learning outcomes were relatively low before the intervention. After the implementation of contextual project learning integrated with Python programming, the posttest scores increased substantially, ranging from 30.00 to 90.00, with a mean score of 61.24 (SD = 13.70). The increase in the mean score from 36.93 to 61.24 suggests an overall improvement in students' learning outcomes following the instructional treatment. Moreover, the similar standard deviation values between the pretest and posttest indicate that the variability of students' scores remained relatively consistent across both measurements.

Pre-Treatment Analysis

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelompok	Statistic	df	Sig.	Statistic	df	Sig.
Nilai Pretest	Eksperimen	,149	30	,088	,928	30	,043
	Kontrol	,196	28	,007	,930	28	,062
Nilai Posttest	Eksperimen	,185	30	,010	,919	30	,025
	Kontrol	,194	28	,008	,899	28	,011

a. Lilliefors Significance Correction

Prior to the implementation of the learning intervention, a normality test was conducted to examine whether the pretest scores were normally distributed. As shown in Table X, the Shapiro-Wilk test indicated that the experimental group did not meet the assumption of normality (W = 0.928, p = 0.043), whereas the control group was normally distributed (W = 0.930, p = 0.062). Since one of the groups violated the normality assumption ($p < 0.05$), the pretest data were considered not normally distributed. Therefore, subsequent analyses involving pretest comparisons should employ a non-parametric statistical test, such as the Mann-Whitney U test.

Ranks

	Kelompok Penelitian	N	Mean Rank	Sum of Ranks
Nilai Pretest Mahasiswa	Ekeperimen	30	28,73	862,00
	Kontrol	28	30,32	849,00
	Total	58		

Test Statistics[a]

	Nilai Pretest Mahasiswa
Mann-Whitney U	397,000
Wilcoxon W	862,000
Z	-,360
Asymp. Sig. (2-tailed)	,719

a. Grouping Variable: Kelompok Penelitian he Mann–Whitney U test was conducted to compare the pretest scores of the experimental and control groups before the intervention. The experimental group (n = 30) obtained a mean rank of 28.73 (sum of ranks = 862.00), while the control group (n = 28) obtained a mean rank of 30.32 (sum of ranks = 849.00). The analysis produced a Mann–Whitney U value of 397.000, Z = −0.360, and p = 0.719. Since $p > 0.05$, there was no statistically significant difference between the two groups, indicating that they had equivalent initial learning outcomes before the implementation of contextual project learning integrated with Python programming.

Post-Treatment Analysis

After the intervention, both groups completed a posttest. Shapiro–Wilk results showed that the posttest scores were not normally distributed in either the experimental (p = 0.025) or control group (p = 0.011). Therefore, the Mann–Whitney U test was used to examine differences in learning outcomes between the two groups after the implementation of contextual project learning integrated with Python programming.

Mann-Whitney Test

Ranks

	Kelompok Penelitian	N	Mean Rank	Sum of Ranks
Nilai Posttest	1,00	30	35,87	1076,00
	2,00	28	22,68	635,00
	Total	58		

Test Statistics[a]

	Nilai Posttest
Mann-Whitney U	229,000
Wilcoxon W	635,000
Z	-3,004
Asymp. Sig. (2-tailed)	,003

a. Grouping Variable: Kelompok Penelitian

Since the posttest scores of both groups did not satisfy the normality assumption, the Mann-Whitney U test was employed to compare students' learning outcomes between the experimental and control groups after the implementation of the instructional intervention. As presented in Table X, the experimental group (n = 30) obtained a mean rank of 35.87 with a sum of ranks of 1076.00, whereas the control group (n = 28) obtained a mean rank of 22.68 with a sum of ranks of 635.00. The higher mean rank of the experimental group indicates that students who participated in contextual project learning integrated with Python programming achieved better learning outcomes than those in the control group. Furthermore, the Mann-Whitney U test produced a U value of 229.000, a Z value of -3.004, and an Asymptotic Significance (2-tailed) value of 0.003. Since the significance value was less than 0.05 ($p = 0.003$), the null hypothesis (H_{02}) was rejected. These findings indicate that there was a statistically significant difference in posttest learning outcomes between the experimental and control groups. Therefore, the integration of Python programming into contextual project learning significantly improved university students' learning outcomes compared with the conventional instructional approach.

To provide a clearer overview of the improvement in students' learning outcomes following the implementation of contextual project learning integrated with Python programming, the descriptive statistics and graphical representations are presented in **Figure X**. The figure summarizes the comparison between the pretest and posttest mean scores, illustrates the distribution of posttest scores across the experimental and control groups, and presents the mean rank comparison obtained from the Mann–Whitney U test.

Table 1. Descriptive Statistics

Variable	N	Mean	SD	Min	Max
Pretest	58	36.93	13.35	10.00	60.00
Posttest	58	61.24	13.70	30.00	90.00

Figure 1. Mean Pretest vs Posttest

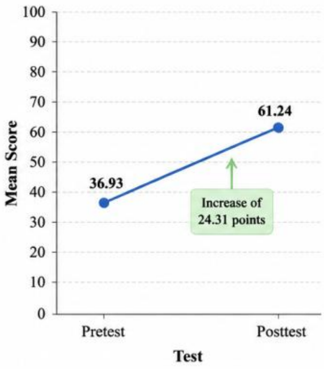


Figure 2. Boxplot of Posttest Scores by Group

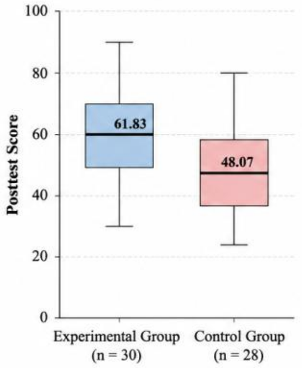
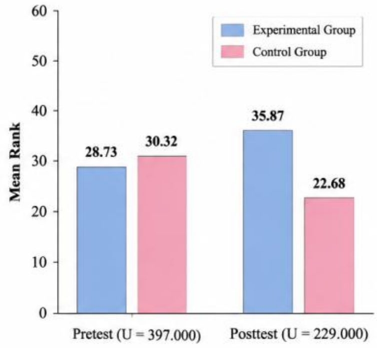


Figure 3. Mean Rank (Mann–Whitney U Test) Pretest vs Posttest



Note. Higher mean scores and mean ranks indicate better learning outcomes. In the posttest, the experimental group outperformed the control group.

As illustrated in Figure X, students demonstrated a substantial improvement in learning outcomes after the implementation of contextual project learning integrated with Python programming. The average score increased from 36.93 on the pretest to 61.24 on the posttest, indicating an increase of 24.31 points. Furthermore, the boxplot shows that the experimental group generally achieved higher posttest scores than the control group. This finding is also supported by the Mann–Whitney U test, in which the experimental group obtained a higher mean rank (35.87) than the control group (22.68), confirming a statistically significant difference between the two groups ($p = 0.003$). Overall, these visual representations strengthen the statistical findings and demonstrate the positive impact of integrating Python programming into contextual project learning on students' learning outcomes.

During the early stages of implementation, several students experienced difficulties in understanding Python syntax, particularly when defining variables, writing simple commands, and performing set operations. Some students also found it challenging to connect mathematical concepts with programming logic. However, collaborative project activities, peer discussions, and lecturer guidance gradually reduced these difficulties. By the end of the intervention, most students were able to independently construct simple Python programs to represent mathematical concepts and solve contextual problems.

DISCUSSION

The findings indicate that integrating Python programming into contextual project learning significantly improved university students' learning outcomes. Before the intervention, both the experimental and control groups demonstrated comparable initial abilities, as indicated by the non-significant Mann–Whitney U test ($p = 0.719$). This finding confirms that the two groups were statistically equivalent prior to treatment, allowing the posttest differences to be attributed to the instructional intervention rather than to students' prior knowledge. The findings of this study are consistent with previous research reporting that contextual learning environments encourage students to construct mathematical understanding through meaningful real-world experiences. The integration of Python programming further strengthened this learning process by enabling students to visualize mathematical concepts, explore multiple solution strategies, and receive immediate computational feedback. These findings support previous studies emphasizing that computational tools can enhance mathematical reasoning, problem-solving skills, and student engagement when integrated into project-based learning. Moreover, the results are in line with studies on didactical design, which argue that instructional activities should be developed based on students' learning trajectories and anticipated learning obstacles. In this study, contextual projects supported by Python programming provided learning experiences that enabled students to connect abstract mathematical concepts with authentic situations, thereby facilitating deeper conceptual understanding.

Following the intervention, the experimental group achieved substantially higher posttest scores (M = 66.50) than the control group (M = 55.61). The Mann–Whitney U test further confirmed a significant difference between the groups (U = 229.000, p = 0.003), while the moderate effect size (r = 0.394) indicates that the intervention had meaningful educational value. These findings suggest that contextual project learning supported by Python programming provides a more effective learning environment than conventional instruction.

A possible explanation is that contextual projects engage students in authentic problem-solving, while Python programming supports computational exploration of mathematical concepts. This combination promotes deeper conceptual understanding, analytical reasoning, and reflective learning. Similar findings were reported by (Hsiao et al., 2023). Likewise, (Karnando et al., 2024) demonstrated that project-based Python learning increased students' conceptual understanding because programming activities enabled learners to apply theoretical knowledge to authentic tasks. Therefore, the present findings reinforce growing evidence that integrating programming with contextual learning creates a more meaningful and effective mathematics learning environment. While the present findings are generally consistent with previous studies, this research also provides a distinctive contribution. Previous studies primarily examined Python programming as a computational tool or project-based learning as an instructional model independently. In contrast, the present study integrates Python programming within contextual project learning, allowing students to connect abstract mathematical concepts with authentic real-life problems through computational exploration. This integrated approach extends existing literature by demonstrating that programming functions not merely as a technical skill but also as a pedagogical medium that supports conceptual understanding and meaningful learning experiences.

The effectiveness of the proposed instructional model can be explained through constructivist learning theory, which argues that knowledge is actively constructed through meaningful experiences. Piaget (1972) emphasized that learners continuously reorganize their cognitive structures when interacting with new experiences, while (Vygotsky, 1978) highlighted the importance of social interaction and collaborative learning in knowledge construction. During contextual projects, students collaborated to analyze problems, develop Python algorithms, evaluate computational outputs, and present their findings. These learning experiences encouraged active knowledge construction rather than passive information acquisition.

The findings also support the principles of Contextual Teaching and Learning (CTL) proposed by (Johnson, 2011), which emphasize connecting academic concepts with real-world situations. In the present study, students solved contextual mathematical problems using Python programming, enabling them to recognize the practical relevance of mathematics. This integration transformed abstract mathematical concepts into meaningful learning experiences, thereby increasing engagement and improving conceptual understanding. (Karnando et al., 2024) found that project-based Python learning significantly improved students' engagement and academic performance through authentic project experiences. Collectively, these studies support the present findings that integrating contextual pedagogy, project-based learning, and Python programming creates an effective instructional approach for improving university students' learning outcomes.

The findings have important implications for mathematics education in higher education. The significant improvement in students' learning outcomes indicates that Python programming functions not only as a programming language but also as an effective pedagogical tool for enhancing conceptual understanding and problem-solving. Ferdiansyah et al., (2025) found that project-based learning enhanced students' mathematical learning outcomes by encouraging active investigation and collaborative problem-solving. The present study extends these findings by demonstrating that integrating Python programming into contextual project learning provides meaningful learning experiences that improve university students' learning outcomes.

Despite the positive findings, several limitations should be acknowledged. First, the study involved only 58 students from a single university, which may limit the generalizability of the findings. Second, the intervention was conducted over a relatively short instructional period, making it difficult to evaluate the long-term impact of contextual project learning integrated with Python programming. Third, the study focused primarily on students' learning outcomes and did not investigate other important variables, such as learning motivation, mathematical creativity, digital literacy, or programming self-efficacy. In addition, although standardized assessment procedures were employed, the interpretation of classroom observations and students' learning processes may have involved a degree of researcher subjectivity. Future research should therefore involve larger and more diverse samples, longer intervention periods, and mixed-method research designs to provide a more comprehensive understanding of the effectiveness of integrating Python programming into contextual mathematics learning.

CONCLUSION

This study concludes that integrating Python programming into contextual project learning is an effective instructional approach for improving university students' learning outcomes in mathematics. The findings demonstrated that both groups had equivalent initial abilities before the intervention, while students who participated in contextual project learning supported by Python programming achieved significantly higher posttest scores than those receiving conventional instruction. The moderate effect size further indicates that the intervention produced meaningful educational benefits beyond statistical significance. These findings suggest that combining authentic contextual projects with computational activities promotes active engagement, conceptual understanding, logical reasoning, and systematic problem-solving, thereby creating a more meaningful learning experience for university students.

The study also contributes to the growing evidence that programming can function as a pedagogical tool rather than merely a technical skill in mathematics education. Integrating Python programming with contextual learning provides opportunities for students to connect mathematical concepts with real-world applications while simultaneously developing computational competencies required in the digital era. Future research is recommended to investigate the long-term impact of this instructional model across different educational contexts, mathematical topics, and larger populations. Further studies should also examine its influence on other educational outcomes, such as mathematical creativity, problem-solving skills, digital literacy, and learning motivation, as well as explore the integration of emerging technologies, including artificial intelligence and learning analytics, to further enhance contextual mathematics learning.

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