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Implementation of Project-Based Learning through Elementary School Teaching Assistance Programs to Enhance Mathematics Conceptual Understanding of Primary Teacher Education Students

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Abstract

Conceptual understanding of mathematics is essential for prospective elementary school teachers, yet primary school teacher education students face challenges in connecting mathematical concepts with classroom practice. This study examined the implementation of project-based learning (PjBL) through elementary school teaching assistance activities to strengthen students' conceptual understanding of mathematics. A mixed-methods approach with an embedded experimental design involved 27 fifth-semester students from class 34A at the Faculty of Education, Universitas Negeri Makassar, who participated in teaching assistance at partner elementary schools in Bone Regency. Data were collected through conceptual understanding tests, observations of PjBL implementation, documentation, and student reflections. Quantitative data were analyzed through pretest–posttest comparisons and normalized gain (N-gain) calculations, while qualitative analysis involved data condensation, data display, and conclusion drawing. The mean conceptual understanding score increased from 46.37 at pretest to 87.85 at posttest, with a mean N-gain of 0.764, categorized as high. The activities also provided authentic experiences in designing, implementing, and reflecting on mathematics instruction in elementary schools. These findings indicate improved conceptual understanding following PjBL implementation and highlight opportunities to connect mathematical knowledge with teaching practice. The study supports the potential of integrating PjBL into teaching assistance programs to strengthen the

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academic and pedagogical preparation of prospective elementary school teachers.

Keywords: Project-Based Learning; Teaching Assistance; Mathematical Conceptual Understanding; Preservice Elementary Teachers; Teacher Education

INTRODUCTION

Primary School Teacher Education plays a strategic role in improving the quality of learning at the elementary education level. Elementary school teachers are not only responsible for mastering instructional content but also play an important role in developing students' critical thinking, creativity, communication, and problem-solving skills from the early stages of education. Therefore, teacher education programs need to prepare prospective teachers who possess both academic competence and pedagogical competence to design meaningful learning experiences that are aligned with the characteristics of 21st-century learners (Darling-Hammond, 2021); (Jentsch & König, 2022).

One of the essential competencies that needs to be developed among Primary School Teacher Education students is a deep understanding of mathematical concepts. Elementary school mathematics has abstract characteristics that require teachers to represent concepts through concrete, visual, and contextual approaches. Mathematics conceptual understanding is not merely related to the ability to obtain correct answers but also includes the ability to explain relationships among concepts, use various forms of representation, provide reasoning for procedures, and apply concepts in different situations (Depaepe et al., 2020); (Tamur et al., 2020); (Goos et al., 2021).

However, several studies have indicated that prospective teachers still experience difficulties in developing conceptual and applicable mathematical understanding. Some students are able to solve mathematical problems procedurally but are not yet fully capable of explaining concepts in depth or developing instructional strategies that support students' understanding of mathematical concepts. This condition indicates a gap between mathematical content knowledge and pedagogical content knowledge (PCK), which refers to the ability to integrate subject matter knowledge with appropriate teaching strategies (Kleickmann et al., 2013); (Dwirahayu et al., 2024).

This issue has become an important concern in teacher education because the quality of mathematics learning in elementary schools is strongly influenced by teachers' competence in understanding concepts and selecting appropriate instructional approaches. Research in teacher education has shown that learning experiences that focus solely on theoretical knowledge are insufficient to develop prospective teachers' professional competencies. Students require authentic learning experiences that enable them to connect academic concepts with real teaching practices in schools (Darling-Hammond, 2021); (Uyen et al., 2023).

One form of authentic experience in teacher education is teaching assistance activities in elementary schools. These activities provide opportunities for Primary School Teacher Education students to engage directly in school environments through observation, lesson planning, teaching practice, learning evaluation, and reflection. Such activities enable students to understand learners' characteristics, identify mathematics learning problems, and develop professional competencies as prospective teachers. Field practice experiences are essential in developing teacher competence because students learn to deal with the complexity of learning situations that are not always encountered in university courses (Riyanti, 2021); (Hafid & Muin, 2023); (Tsalist et al., 2024); (Suwono & Prasetyo, 2026).

Theoretically, field experience activities are closely related to the concept of *experiential learning* developed by Kolb. This theory explains that effective learning occurs through a cycle consisting of concrete experience, reflection on experience, conceptual formation, and application of concepts in new situations (Kolb, 2015). In the context of teacher education, teaching experiences provide opportunities for students to develop professional knowledge through reflection on their pedagogical actions. Therefore, teaching assistance activities in elementary schools require a learning approach that can optimize students' processes of experiencing, investigating, and reflecting.

One of the approaches that is relevant to these needs is *Project-Based Learning* (PjBL). PjBL is a learning model that positions students as the center of learning activities through the completion of authentic problems in the form of specific projects. This model involves processes of problem identification, planning, investigation, collaboration, product development, presentation of results, and reflection. Through these processes, students not only acquire theoretical knowledge but also develop critical thinking, creativity, communication, and problem-solving skills (Chen & Yang, 2022); (Yusri et al., 2024).

In teacher education, PjBL has the potential to improve students' pedagogical competence because it provides direct experiences in designing and implementing learning activities. Students do not merely learn about instructional concepts but also experience the process of developing learning activities based on learners' needs. Research by (Alrajeh, 2021) demonstrated that the implementation of PjBL among prospective teachers improved their ability to develop teaching skills through the process of planning and completing instructional projects. This finding is supported by (Nasution et al., 2021), who reported that prospective mathematics teachers responded positively to PjBL implementation because it increased their engagement and understanding of the mathematics learning process.

In the context of mathematics learning, PjBL is relevant because it enables students to connect mathematical concepts with real-world problems. Primary School Teacher Education students can develop learning projects in the form of mathematics learning media, concept exploration activities, or learning designs based on students' surrounding environments. Through these activities, students learn how mathematical concepts can be transformed into concrete learning experiences that are easier for elementary school students to understand (Diego-Mantecon et al., 2021).

Research by (Lee & Galindo, 2021) demonstrated that project-based learning approaches have positive effects on mathematics learning. (Simatupang et al., 2026) found that PjBL improved elementary school students' mathematics learning outcomes through learning activities involving exploration and the creation of tangible products. Furthermore (Sukaji & Hartono, 2026) explained that activity-based and contextual mathematics learning can enhance conceptual understanding because students are actively involved in the process of constructing knowledge. These findings indicate that mathematics learning requires approaches that provide direct learning experiences rather than focusing solely on procedural problem-solving.

In addition to improving academic abilities, PjBL also contributes to the development of professional competencies among prospective teachers. (Tsybulsky et al., 2020) found that participation in project-based learning experiences helped prospective teachers understand the learning process more reflectively and increased their readiness to engage in teaching practice. This indicates that PjBL can serve as a bridge between theoretical knowledge acquired in higher education and the practical demands of classroom instruction.

Although research on PjBL has developed extensively, most existing studies have focused on the implementation of this model to improve elementary school students' learning outcomes or to develop general skills among university students. Studies that specifically integrate PjBL with teaching assistance activities for Primary School Teacher Education students to improve mathematics conceptual understanding remain relatively limited. This issue is particularly important because Primary School Teacher Education students are not only required to understand mathematical concepts but also expected to transform these concepts into learning experiences that are appropriate to the characteristics of elementary school students.

Based on this research gap, this study proposes the integration of Project-Based Learning into teaching assistance activities in elementary schools as a strategy for developing the competencies of Primary School Teacher Education students. This study not only examines the improvement of students' mathematics conceptual understanding but also investigates how project-based experiences support students in developing pedagogical abilities to design contextual mathematics learning.

Therefore, this study aims to analyze the implementation of Project-Based Learning through teaching assistance activities in elementary schools in improving mathematics conceptual understanding among Primary School Teacher Education students at the Faculty of Education, Universitas Negeri Makassar. The findings of this study are expected to provide theoretical contributions to the development of experience-based teacher education and practical implications for improving mathematics learning in primary school teacher education programs.

METHODS

This study employed a mixed-methods approach with an embedded experimental design. This design was selected because the study aimed to analyze the improvement of students' mathematics conceptual understanding quantitatively while also obtaining an in-depth description of the implementation process of Project-Based Learning (PjBL) through teaching assistance activities in elementary schools. Quantitative data were used to identify changes in students' mathematics conceptual understanding based on pretest and posttest results, whereas qualitative data were used to describe the project implementation process,

students' experiences, and reflections throughout the teaching assistance activities (Creswell & Plano, 2023).

The research was conducted in the Primary School Teacher Education Study Program, Faculty of Education, Universitas Negeri Makassar, through teaching assistance activities at partner elementary schools in Bone Regency, South Sulawesi, Indonesia. The research participants were fifth-semester Primary School Teacher Education students from class 34A, consisting of 27 students. The participants were selected using purposive sampling with the consideration that they had acquired fundamental knowledge of education and elementary school mathematics learning and participated in the entire series of teaching assistance activities.

The implementation of PjBL in teaching assistance activities involved several stages: (1) identifying mathematics learning problems through observations at partner schools; (2) designing learning projects in the form of mathematics instructional materials and learning media; (3) implementing projects through teaching activities in elementary schools; and (4) evaluating and reflecting on the learning process. These stages were designed to provide authentic experiences for students in developing their mathematics conceptual understanding while applying mathematical concepts in elementary school learning contexts.

The research instruments consisted of a mathematics conceptual understanding test, an observation sheet for PjBL implementation, activity documentation, and student reflection sheets. The mathematics conceptual understanding test was used to measure students' abilities before and after the implementation of PjBL, with indicators including the ability to explain concepts, use mathematical representations, establish relationships among concepts, and apply concepts in problem-solving situations. Observation sheets and reflection sheets were used to obtain data regarding students' experiences in designing and implementing project-based mathematics learning.

Quantitative data were analyzed using descriptive statistics and improvement analysis through the Normalized Gain (N-Gain) score to determine the level of change in students' mathematics conceptual understanding. Qualitative data obtained from observations, documentation, and student reflections were analyzed using the analytical model proposed by (Miles et al., 2020)which consists of data condensation, data display, and conclusion drawing. The validity of qualitative data was ensured through source and technique

triangulation by comparing findings from observations, documentation, and student reflections.

RESULTS

Implementation of Project-Based Learning through Teaching Assistance in Elementary Schools

Project-Based Learning (PjBL) through the Teaching Assistance in Elementary Schools program was implemented by students of the Elementary School Teacher Education Program, Faculty of Education, Universitas Negeri Makassar, at partner schools in Bone Regency. The program was designed to provide students with direct experience in designing and implementing project-based mathematics learning in elementary school settings.

The implementation of Project-Based Learning through the Teaching Assistance in Elementary Schools program was observed based on four main stages: identification of mathematics learning problems, learning project design, project implementation at partner schools, and learning evaluation and reflection. The observation results are presented in Table 1.

Table 1. Observation Results of Project-Based Learning Implementation through Teaching Assistance in Elementary Schools

No	PjBL Stages	Number of Indicators	Maximum Score	Obtained Score	Percentage (%)	Category
1	Identification of mathematics learning problems	4	16	14	87,5	Very Highly Implemented
2	Learning project design	6	24	22	91,1	Very Highly Implemented
3	Project implementation at partner schools	8	32	29	90,6	Very Highly Implemented
4	Learning evaluation and reflection	6	24	21	87,5	Very Highly Implemented

As shown in Table 1, the implementation of Project-Based Learning through the Teaching Assistance in Elementary Schools program demonstrated a very high level of implementation. Overall, the program obtained a score of 86 out of a maximum score of 96, equivalent to 89.6%, and was therefore classified as very highly implemented.

The identification of mathematics learning problems achieved an implementation rate of 87.5%. At this stage, the students observed mathematics learning processes to identify learners' needs and learning difficulties. The observation results were then used as the basis for determining the mathematical concepts to be developed through project-based activities.

The learning project design stage achieved the highest implementation rate, at 91.7%. The results indicate that the students were able to prepare instructional materials, develop mathematics learning media, and design activities aimed at promoting conceptual understanding. The learning activities were not limited to solving mathematical problems but also incorporated exploration and problem-solving activities.

The project implementation stage at partner schools achieved an implementation rate of 90.6%. At this stage, the students conducted mathematics instruction directly in elementary school classrooms and acted as learning facilitators. They integrated mathematical concepts with instructional strategies, learners' characteristics, the use of learning media, and classroom management throughout the project activities.

The learning evaluation and reflection stage achieved an implementation rate of 87.5%. The students evaluated the learning processes they had implemented and identified strengths, weaknesses, and aspects requiring improvement. The results of the reflection were then used as a basis for improving subsequent instructional plans.

Overall, the findings indicate that all stages of Project-Based Learning through the Teaching Assistance in Elementary Schools program were implemented at a very high level. The consistently high implementation rates across all stages demonstrate that the students were able to integrate their understanding of mathematical concepts with the planning, implementation, evaluation, and reflection of mathematics instruction in elementary school settings.

Improvement in Students' Mathematical Conceptual Understanding through Project-Based Learning

The improvement in students' mathematical conceptual understanding was analyzed based on the pretest and posttest scores of 27 fifth-semester students from Class 34A of the Elementary School Teacher Education Program, Faculty of Education, Universitas Negeri Makassar. The results of the descriptive statistical analysis are presented in Table 2.

Table 2. Descriptive Statistics of Students' Mathematical Conceptual Understanding

Statistic	Pretest	Posttest
Number of students	27	27
Minimum score	33	80
Maximum score	60	91
Mean	46,37	87,85
Standard deviation	8,50	3,30

As shown in Table 2, the mean score of students' mathematical conceptual understanding increased from 46.37 on the pretest to 87.85 on the posttest. The minimum score increased from 33 to 80, while the maximum score increased from 60 to 91. The standard deviation also decreased from 8.50 on the pretest to 3.30 on the posttest. These results indicate an increase in students' mathematical conceptual understanding scores after participating in Project-Based Learning through the Teaching Assistance in Elementary Schools program. To determine the magnitude of the improvement, a Normalized Gain (N-Gain) analysis was conducted. The results are presented in Table 3.

Table 3. Categories of Improvement in Students' Mathematical Conceptual Understanding

Gain Coefficient	Number of Students	Percentage (%)	Classification
$g < 0.3$	0	0	Low
$0.3 \leq g < 0.7$	9	33,33	Moderate
≥ 0.7	18	66,67	High
Total	27	100	High

The analysis showed that the mean N-Gain score was 0.76, which was classified as high. A total of 18 students, or 66.67%, achieved improvement in the high category, while 9 students, or 33.33%, were classified in the moderate category. No students were classified in the low improvement category.

DISCUSSION

Implementation of Project-Based Learning through Teaching Assistance in Elementary Schools

The implementation of Project-Based Learning (PjBL) through the Teaching Assistance in Elementary Schools program was designed to provide authentic learning experiences for students of the Elementary School Teacher Education Program in developing project-based mathematics instruction. This activity positioned the students not only as implementers of instruction but also as designers of learning experiences who were

responsible for connecting mathematical concepts with the learning needs of elementary school students.

The implementation of PjBL through the Teaching Assistance in Elementary Schools program consisted of four main stages: identification of mathematics learning problems, learning project design, project implementation at partner schools, and learning evaluation and reflection. During the problem identification stage, the students observed mathematics learning processes at partner schools in Bone Regency to identify learners' needs and learning difficulties. The results of these observations served as the basis for determining the mathematical concepts to be developed through project activities.

The project design stage involved preparing instructional materials, developing mathematics learning media, and designing learning activities oriented toward conceptual understanding. The students began to develop learning activities that did not focus solely on solving mathematical problems but also provided opportunities for learners to understand mathematical concepts through exploration and problem-solving activities.

During the implementation stage, the students conducted mathematics instruction directly at the partner schools. They acted as facilitators who guided learners in discovering and understanding mathematical concepts through project activities. This process provided the students with opportunities to apply the pedagogical knowledge acquired during their university courses in authentic classroom contexts. The observation results showed that PjBL-based Teaching Assistance in Elementary Schools provided more meaningful learning experiences for the students than learning activities that focused solely on theoretical knowledge. The students had opportunities to understand the relationships among mathematical concepts, instructional strategies, learners' characteristics, and classroom management.

These findings are consistent with the concept of experiential learning, which emphasizes direct experience as an important component in the development of professional knowledge. Through concrete experiences, reflection, and the application of concepts in real-world situations, preservice teachers can develop a deeper understanding of instructional practices (Kolb, 2015). The findings also support (Lee & Galindo, 2021), who reported that the implementation of PjBL among preservice mathematics teachers can improve their ability to design instruction and understand the complexity of implementing project-based learning in classroom settings. Therefore, the integration of PjBL into the Teaching Assistance in

Elementary Schools program provides opportunities for students to develop academic and pedagogical competencies simultaneously.

Despite the positive outcomes, the implementation of PjBL through the Teaching Assistance in Elementary Schools program also presented several challenges. Based on the students' reflections, the main challenges included limited time for project implementation, differences in elementary school students' abilities, and the need to adjust project designs to classroom conditions. These conditions indicate that successful PjBL implementation depends not only on the quality of project design but also on the students' ability to adapt during the learning process.

The students needed to consider learners' characteristics, the availability of learning resources, and instructional time to ensure that the projects could be implemented effectively. This finding is consistent with (Sukaji & Hartono, 2026), who explained that PjBL implementation requires careful planning, a supportive learning environment, and educators' ability to manage project activities effectively. In this study, these challenges became part of the students' professional learning process. By dealing with authentic problems during the Teaching Assistance in Elementary Schools program, the students had opportunities to reflect on their teaching practices and improve the instructional strategies they had developed

Improvement in Students' Mathematical Conceptual Understanding through Project-Based Learning

The increase in the mean score from 46.37 on the pretest to 87.85 on the posttest indicates an improvement in students' mathematical conceptual understanding after participating in Project-Based Learning through the Teaching Assistance in Elementary Schools program. The mean N-Gain score of 0.76, which was classified as high, further supports this improvement. This improvement can be associated with the characteristics of PjBL, which position students as active participants in the construction of knowledge. Students were not only exposed to mathematical concepts theoretically but were also required to apply these concepts in problem analysis, instructional planning, learning media development, and the implementation of mathematics instruction in elementary school settings.

This finding supports (Chen & Yang, 2022), who explained that PjBL can improve academic achievement because learners are actively engaged in authentic problem-solving

processes. Project-based activities provide students with opportunities to connect theoretical knowledge with practical needs, thereby promoting a deeper understanding of concepts. The findings are also consistent with (Diego-Mantecon et al., 2021), who showed that project-based mathematics learning can support conceptual understanding through exploration, representation, and the application of mathematics in real-world contexts. In this study, the students were required to transform abstract mathematical concepts into learning experiences that could be understood by elementary school learners. This process required them to develop a deeper understanding of the concepts before presenting them in classroom instruction.

In addition to the improvement in conceptual understanding, the implementation of PjBL through the Teaching Assistance in Elementary Schools program also indicated the development of students' pedagogical competence. Based on observations and activity documentation, the students showed improvement in their ability to design instruction, select appropriate instructional strategies, develop mathematics learning media, and evaluate the learning process. Prior to participating in the Teaching Assistance in Elementary Schools program, most of their mathematics learning experiences were obtained through university-based coursework. Through project-based activities at partner schools, the students gained opportunities to understand how mathematical concepts could be translated into learning experiences that were appropriate for the characteristics of elementary school learners.

These changes indicate that teaching practice plays an important role in the development of preservice teachers' professional competence. The students not only developed an understanding of "what to teach" but also of "how the concepts should be taught." This finding is consistent with (Suwono & Prasetyo, 2026), who reported that teaching practice contributes to improving preservice teachers' readiness to design and implement instruction.

The findings also align with (Depaepe et al., 2020), who argued that mathematics teachers' competence is determined not only by their mastery of subject matter but also by their ability to transform mathematical knowledge into effective instructional strategies. In the context of teacher education, PjBL-based Teaching Assistance in Elementary Schools provided experiences that supported the development of students' pedagogical content knowledge. The students learned to integrate mathematical knowledge, understanding of

learners, instructional strategies, and learning evaluation into a coherent instructional process.

CONCLUSION

This study demonstrates that the implementation of Project-Based Learning (PjBL) through teaching assistance activities in elementary schools improved the mathematics conceptual understanding of Primary School Teacher Education students at the Faculty of Education, Universitas Negeri Makassar State O. The implementation of PjBL through the stages of problem identification, project design, learning implementation, and reflection provided authentic experiences for students in connecting mathematical concepts with teaching practices in elementary schools. The improvement in students' conceptual understanding was indicated by an increase in the mean score from 46.37 in the pretest to 87.85 in the posttest, with an average N-Gain score of 0.764, which was categorized as high. In addition to improving conceptual abilities, PjBL-based teaching assistance activities also supported the development of students' pedagogical competence through experiences in designing, implementing, and evaluating mathematics learning at partner schools in Bone Regency. Therefore, integrating PjBL into teaching assistance activities in elementary schools can serve as a relevant instructional strategy for preparing Primary School Teacher Education students as prospective elementary school teachers who are able to understand mathematical concepts deeply and apply them in contextual learning environments.

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