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ENHANCING PRE-SERVICE MATHEMATICS TEACHERS' REPRESENTATION SKILLS THROUGH GEOGEBRA-INTEGRATED PROBLEM BASED LEARNING

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Abstract

Mathematical representation is an important element in understanding, explaining, and solving real-world phenomena. The lack of learning oriented to real problems causes low representation ability. The purpose of this study was to determine the improvement of mathematical representation ability through problem-based learning assisted by GeoGebra. This study is a qualitative study. The subjects of the study were odd-semester students in the year 2024/2025 who took basic geometry courses. Data collection was carried out by observation and testing. The instruments used were observation sheets and test questions declared valid by experts in the field of mathematics learning. The data in this study were analyzed by quantitative descriptive analysis. The results showed that the N-Gain was 0.47 with a medium category, which means that the application of PBL assisted by GeoGebra was effective in students' representation abilities. The conclusion is that problem-based learning assisted by GeoGebra can improve students' mathematical representation abilities. This study provides meaning for implementing problem-based learning assisted by GeoGebra.

Keywords: Geogebra; mathematical representation; PBL.

Abstrak

Representasi matematis menjadi elemen penting dalam memahami, menjelaskan, dan memecahkan fenomena dunia nyata. Minimnya pembelajaran berorientasi pada masalah nyata menyebabkan rendahnya kemampuab representasi. Tujuan penelitian ini untuk mengetahui peningkatan kemampuan representasi matematis melalui integrasi problem based learning dan geogebra. Penelitian ini merupakan penelitian tindakan kelas dengan dua siklus. Subjek penelitian mahasiswa semester ganjil tahun 2024/2025 yang menempuh mata kuliah geometri dasar berjumlah 16 mahasiswa. Pengumpulan data dilakukan dengan observasi dan tes. Intrumen yang digunakan berupa lembar observasi dan soal tes telah dinyatakan valid oleh ahli bidang pembelajaran matematika. Data dalam penelitian ini dianalisis dengan analisis deskriptif kuantitatif. Hasil penelitian menunjukkan bahwa N-Gain 0,47 dengan kategori sedang yang berarti penerapan problem based learning PBL berbantu Geogebra efektif terhadap peningkatan kemampuan representasi mahasiswa. Kesimpulannya adalah problem based learning berbantu Geogebra dapat meningkatkan kemampuan representasi matematis mahasiswa. Penelitian ini memberikan implikasi untuk mengimplementasikan problem based learning berbantu Geogebra.

***Kata kunci**: Geogebra; PBL; Representasi Matematis.*

INTRODUCTION

The National Council of Teachers of Mathematics (NCTM) states that there are five process standards in mathematics learning: problem solving, communication, reasoning and proof, connections, and representation. Mathematical representation is a crucial aspect of mathematics learning, serving as the basis for students' understanding of

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mathematical ideas and their use in solving mathematical problems (Wulandari, 2019). Representational ability is the ability to express mathematical ideas in various forms, including images, tables, graphs, numbers, letters, symbols, and other representations, in order to solve mathematical problems (Hardianti & Effendi, 2021). Students with strong representational skills are able to effectively communicate mathematical ideas in the form of symbols, images, tables, or verbal language. Although representational ability has been established as one of the process standards that students must achieve through mathematics learning, its implementation still faces various challenges. Teachers' limited understanding and students' conventional learning habits in the classroom hinder the optimal development of students' representational abilities.

Based on the results of the pre-survey, it was found that the average representation ability of students in the basic geometry course is relatively low. Students still have difficulty in presenting mathematical ideas in real problems in an appropriate form. Students solve problems only in algebraic form and still experience errors. Students have not been able to visualize real problems in both planes and space. Classroom learning has been carried out through group discussions, but it is not optimal because many students are still inactive, and the lecturer mostly explains the material. Lecturers' presentation of material is still limited to conventional representations in the form of mathematical symbols and minimally presents real problems in learning. This results in students only imitating what the teacher presents without being given the opportunity to develop other representations. Therefore, the ability to represent mathematical ideas needs to be improved through learning with a contextual approach.

Technological advances in education offer significant opportunities for the development of contextual learning models that support improved learning quality, particularly in repre-sentational skills. The use of technology, particularly in mathematics learning, has been shown to help visualize abstract concepts more concretely and more easily understood, as well as facilitate independent and collaborative exploration of ideas (Putri & Sutarni, 2025).

One approach that is increasingly being used is Problem-Based Learning (PBL). PBL is a learning model that emphasizes active student involvement in solving real-world problems as a means of developing conceptual understanding, thinking skills, and problem-solving abilities. PBL is also considered effective in developing students' representational skills because it involves a process of exploration and reflection on various solutions. PBL provides a real-world context and encourages students to actively solve problems, think, and collaborate. PBL is a learning approach that places students in real-world situations through case studies. This approach emphasizes analytical skills, critical thinking, and decision-making, so students can better understand mathematical concepts in real-world contexts. According to Masruro et al. (2021) and also Wrenn and Wrenn (2009), PBL is effective in increasing student engagement and higher-order thinking skills. Research by Anwar and Rahmawati (2024) found that case-based learning is effective in improving conceptual understanding and encouraging active student participation in group discussions. Furthermore,

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Masriah et al. (2023) and Salsabila et al. (2023) found that PBL influences mathematics learning outcomes. The use of a case study-based learning model, or case method, can improve students' creative and critical thinking skills and help them analyze cases from multiple perspectives to find optimal solutions (Hodijah et al., 2022). By presenting real-world scenarios, students are challenged to explore information, identify problems, and find applicable solutions. In PBL, students are presented with a real-world problem, then design and manage the investigation process, exploring and determining the type of information to collect and the appropriate solution to implement. Throughout the learning process, students collaborate with each other and actively participate in the assessment process of their learning (Sutarsa & Puspitasari, 2021).

However, in practice, the implementation of PBL still faces challenges, particularly in helping students develop accurate and in-depth representations of the concepts being studied. Representation, whether verbal, symbolic, graphical, or numerical, is a crucial skill for students to master, particularly in fields that require strong conceptual understanding, such as mathematics. The limitations of conventional learning media are often a major obstacle to improving students' representational skills.

On the other hand, the use of software-based technology such as GeoGebra can be a solution to overcome these obstacles. When combined with GeoGebra technology, the potential for improving representational capabilities is even greater. GeoGebra, as interactive mathematics software, provides visualization tools that support the dynamic exploration of mathematical concepts. By utilizing GeoGebra, it is possible to provide interactive visual simulations, thereby helping students understand geometric concepts more deeply. Furthermore, using GeoGebra provides opportunities for students to learn independently with user-friendly features. Utilizing GeoGebra in geometry learning can support more effective learning preparation, clarify conceptual understanding, and encourage the mathematics learning process (Mensah, 2023; Safrida et al., 2020). In addition, Geogebra provides an interactive learning experience, allowing students to explore geometric concepts in more depth and contributing to improved learning outcomes (Astuti, 2023). According to Hohenwarter and Preiner (2007), integrating GeoGebra into mathematics learning can improve students' understanding of complex material through interactive visualization. Then, Erlinawati (2018) explained that GeoGebra's simple interface makes it an ideal interactive software for conveying various mathematical concepts. GeoGebra also features engaging animations that can boost student motivation in learning mathematics. Hidayat (2021) explained that GeoGebra can be used as a learning tool in various activities, such as a demonstration and visualization tool. For example, GeoGebra can be used to draw tangents to circles, create pyramid nets, draw triangles with circumcircles, and serve as a tool for confirming mathematical concepts. GeoGebra, a mathematical visualization software, helps students represent ideas in the form of dynamic graphs, interactive models, and in-depth algebraic geometry visualizations. GeoGebra is a dynamic mathematics software that allows users to visualize mathematical concepts interactively through graphs, animations, and the manipulation of

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geometric objects. The combination of PBL and GeoGebra is believed to provide a richer learning experience, helping students understand concepts visually and deeply, and improving their representation skills.

In this context, it is important to examine the effectiveness of GeoGebra-assisted Problem-Based Learning (PBL) in improving students' mathematical representation skills. This research is expected to make a significant contribution to the development of more effective learning methods, particularly in mathematics education. Furthermore, this research can also provide educators with insights into integrating technology with problem-based learning approaches to create more meaningful learning experiences for students. This study aims to determine the improvement of mathematical representation skills through the integration of problem-based learning and GeoGebra.

METHOD

This research is Classroom Action Research. Type of this research accordance to research soal that is for increase ability representation and response student in assisted PBL learning Geogebra in progress in a way natural. This research design uses classroom action research stages, which include planning, action/implementation, observation, and reflection. (Arikunto et al., 2021). The stages study presented in Figure 1.

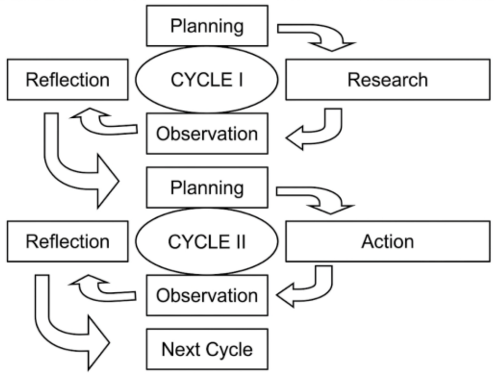

Figure 1. Action Cycle

Figure 1 shows a cycle in the study in a repeated and continuous way to increase the quality of learning, specifically the representation of mathematical students. In Cycle I, researchers plan actions, implement learning (actions), make observations, and then reflect to evaluate the results. The results of the reflection are used to improve the process in Cycle II, and continue. to cycle next until the obtained results are as expected.

As for the activities, every stages presented in Table 1.

Table 1. Activities stages study :

Stages	Activity
1. Planning	a. Analyze problems and causes b. Assembling the device learning in the form of RPS, sheets Work students , media instruments tests and sheets observation c. Do validation expert to device learning d. Revision device learning
2. Action	Implementation plan assisted PBL learning Geogebra in the eyes studying geometry base
3. Observation	Observation activity students and lecturers during implementation learning
4. Reflection	a. Analyze results observation For evaluation success and obstacles b. Formulating corrective actions For cycle next

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This study was conducted in the UM Metro mathematics education study program especially in odd semester and acade-mic year 2024/2025. The subject of this study were 16 students in Mathematics Education study program, who studied Basic Geometry course. Object of this study is students' repre-sentation ability in learning geometry. The instrument used was a test related to representation ability and direct observation sheets in the form of field notes when providing action. Research data consists of qualitative data and quantitative data. Qualitative data in the form of observation data on student activity in learning geometry with assisted PBL implementation geogebra, while quantitative data in the form of test results represent the ability repre-sentation of students. Procedures data collection was carried out with direct observation during learning ongoing and testing of ability representation. Observation done to obtain activity data from lecturers and students during learning on going. Observation conduc-ted by lecturers' field knowledge edu-cation mathematics in a way, directly on each implementation done observation direct. For see the activity of students and teachers in learning.

Next, a test was done for all students who are studying basic geometry. Test used to obtain related data on the ability representation of students before and after learning. Stages study This through two cycle with each cycle having 4 meetings, where each cycle an action is carried out (meeting) First until third) in the form of implementation Problem Based Learning assisted by Geogebra which was planned in advance, and the end every cycle (meeting fourth) given a test for see ability representation s as a basis for reflection and seeing improvements ability representation. Five indicators of mathematical representation ability used in test that is 1) able using repre-sentation picture (visual) to complete problem mathematics; 2) able to change data/information from one represen-tation to another representation in the form of a diagram , graph or table and complete problem mathematics using words or written explanation (verbal representation) ; 3) able to create mathe-matical models from given repre-sentations and solve problems through mathematical expressions; 4) able to drawing geometric patterns, explaining l steps to solve problems using words and resolving them with mathematical expressions; and 5) able to design problem scenarios based on the data or representations provided (Fitrianna et al., 2018).

Data analysis was carried out in both quantitative and qualitative ways. Quantitative data for the see improvement ability representation with the use of the N-Gain formula as follows (Hake, 2002):

$$\text{N-Gain} = \frac{\text{skor postest} - \text{skor pretest}}{\text{skor ideal} - \text{skor pretest}} \quad \ldots\ldots 1$$

N-Gain criteria are defined in Table 2 (Meltzer, 2002).

Table 2. N-Gain Criteria

N-Gain	Criteria
0,70 ≤ N-Gain ≤ 1,00	Tall
0,30 ≤ N-Gain < 0,70	Currently
0,00 ≤ N-Gain < 0,30	Low

Based on Table 2, the indicators' success study obtained a minimum N-Gain on the criteria of moderate. Qualitative data in the form of results observation were described for identifying student involvement in PBL implementation and the utilization of GeoGebra in building mathematical representations.

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RESULTS AND DISCUSSION

Study implemented in the study program of education mathematics for odd semester student's year 2024/2025 academic year. Research has been implemented for 2 cycles, with each cycle consisting of 4 meetings. Implementation cycle I becomes base repair Cycle II. Research done as many as eight meetings, with a duration 2 x 50 minutes, meeting one, two, three, five, six, and seven, delivery material with assisted PBL stages Geogebra, meeting 4 and 8 evaluation with a test ability representation. Research implementing assisted PBL Geogebra in the course geometry base with stages, orientation problem, organizing students, research, presentation results work, and evaluation. During implementation observer learning observes activity of the student in accordance with the stages of learning that have been planned previously. In learning student made in group consisting of 3-4 students. Group arranged in a heterogeneous academic way. Learning is done through 3 activities, namely 1) Preliminary stage that is the lecturer conveying CPL, CPMK and its importance material as well as check understanding student to material prerequisites; 2) The core stage consists of assisted PBL stages Geogebra; 3) Closing stage that is the delivery of the conclusion, evaluation, and action carried out in learning. At every stage's learning lecturer plays a role as a facilitator, with guide student through submission questions, guide use facilitate student For find solutions.

Based on results observation in a way direct show that during the learning process, lecturers and students has do stages designed learning previous. Activity student in learning presented in Table 3.

Table 3. Activities Student

Activity	Cycle I	Cycle II
Orientation problem	45%	80%
Organize	60%	85%
Investigation	45%	75%
Presentation of Results	35%	80%
Evaluation	35%	75%

Table 3 shows improvement activities in all aspects of student activity from cycle I to cycle II. Improvement is highest in activity presentation results, followed by activities evaluation, investigation, orientation problems, and organizing. This shows that the student is more skilled in identifying problems and communicating the ideas and findings.

In cycle I, the majority of students in every aspect are still classified as low. Aspect organize own highest achievement, namely 60%, while other aspects are still 45% or below. Meanwhile, in cycle II, the activity student all aspect Already reaching 75% and above. This means the majority student Already involved in activities in every aspect.

Activity learning is divided into 3 parts: introduction, main body, and conclusion. At the stage of introduction, both cycles I and II have been implemented with good results. Activity learning started with the lecturer delivering the CPL and CPMK, which are assigned to the material conveying how the concepts taught are applied in the workplace, daily life, and real-life problems. In addition, cycle I also explains the related technical use of GeoGebra. Observation results show that the student has listen explanation of the beginning lecturer about CPL, CPMK, and its importance material both in cycles I and II. In addition, in cycle I, the technical use GeoGebra and learning will be done. Most of students

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state already know Geogebra. However, a number of student's never use or not familiar yet about how to use Geogebra. To overcome this matter, the lecturer gives material related to GeoGebra for studied outside class in the form of GeoGebra tutorial references through YouTube. In cycle II, all students already have the application GeoGebra and are already capable use through the tutorial provided. This shows students have enthusiastic talent in learning with GeoGebra. This is a very supportive activity learning at the meeting next. This is shown start. In the second meeting, students were more focused on the geometry material, no longer on how to use GeoGebra. The learning activities carried out by the lecturer in the preliminary stage motivate students to study seriously, so that students will be active during learning.

Furthermore, the core activities in cycles I and II consist of activity orientation, problem solving, organizing, investigating, and presenting results. This activity begins with an problem orientation that is presentation-relevant issues with the material. In this activity, the lecturer give relevant and explanatory description of issues, and will given problem. In addition, the lecturer also provide storytelling with tell invention important things that makes problem feel real around students. Lecturers guide students with questions to stimulate curiosity. The orientation stage in cycle I is still found a lot of students who are not involved and active yet. This is shown from the results observation, only 45% of students are actively involved, meaning that there are 55% of students Not yet involved in the activity orientation problem. This is shown that a lot of students who have not been involved in answering questions, lecturing, and submit question early; besides it also a number of student's Still hesitant to get involved in ask answer For analysis problems. This indicates that Still Lots student has not yet been triggered by the desire he knows of the problems presented. In the results observation, the notes indicate that the student did not yet understand and had insufficient understanding of certain related terms or draft prerequisites used in the problem, so that cause student to still doubt. In this first cycle, the lecturer still predominantly provides guidance in the analysis of the given problem. For that, it is necessary to make improvements at this stage. The lecturer must ensure understanding student will draft a previously related problem. Orientation stage in cycle II, activity orientation. Already reached 80%, and experienced improvement compared to cycle I. In cycle II, the activities stage orientation is the same as cycle I; however lecturer is not dominant in the analysis problem. The lecturer has to review to ensure understanding of the draft prerequisite, and remind return draft prerequisite in teaching materials. This stage majority student Already do analysis of the given problem in a way group. Observation results show that the student is already involved active answer questions lecturer and submit question, beginning in frame do analysis problem. Through the question guide from lecturers, students has capable identify elements key the given problem. This shows that the problems given in cycle II provide a sense of curiosity for students and also students has understand draft prerequisites used in the problem, so that make it easier student in analysis problem. Activity students and lecturers at the time the presentation problem is presented in Figure 2.

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Figure 2. Activity presentation problem

At the stage of organizing, cycle I reached 60%, things This show Still there are 40% of students not yet involved and active in organizing. Observation results obtained from activities carried out student including distribution task member groups and search source references based on identification problems at the stage previously and determining the resolution strategy. Findings at this stage: This Still Lots student has difficulty finding source-relevant references and resolution strategies. In addition, some students' enthusiasm is still not enough, so that cause not enough active in carrying out assigned tasks in groups. Findings from this have led to improvements in the second cycle II, which is giving facility source-related references and assistance to lecturers in each group with questions related to the discovery of resolution strategies. Corrective actions. This is very effective for activities in cycle II. This shows an increase of 25% compared to cycle I, namely 85% of students do activity organizing in cycle II. This means the majority student Already active carry out distribution assignments, searching for relevant references, and determining settlement strategies problem. Activity students at this stage. This presented in Figure 3.

Figure 3. Activity organize

Next, the stage investigations in cycle I obtained 45% result, this show Still Lots found student Not yet been involved in the investigation to find a solution to the problem. To overcome this problem, the lecturer provided intensive guidance with the help of GeoGebra to present the solution to the problem. This action is very effective, with a shown existence improvement by 30%, namely, to 75% of students do activities stage investigation in cycle II. With the guidance of the lecturer, cycle stage II, these students are actively discussing independently, and lecturers are no longer dominant in providing guidance in solving problems. Activity student moment investigation presented in Figure 4.

Figure 4. Activity investigation

Presentation stage results. In cycle I, each group presenting the results of their discussion in front of the class was not yet fully independent, as they still needed a lot of guidance from the lecturer regarding the accuracy of the material presented. Meanwhile, students in other groups also needed time to

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understand the explanations from the presenting group. To overcome this, the lecturer provided clear, specific, and positive feedback to encourage self-confidence and a spirit of curiosity to learn the next material. This had a positive impact, as shown in the changes during the presentation of work results in cycle II, namely that the lecturer was no longer dominant in providing guidance or correcting conceptual errors. The results of observations also showed that the existence improvement activity of students at this stage increased to 80%.

In the closing stage, each group was able to draw conclusions from each meeting. At this stage, the lecturer provided reinforcement by asking short questions to ensure understanding and emphasize key points of the material. Each group was also able to reflect on their learning. The learning reflection contained notes related to the answers to the questions: what did I learn? What was the most challenging? What did I not understand? The results of the learning reflection were presented at the end of the meeting. Evaluation activities were carried out at the fourth and eighth meetings by administering a written test. The evaluation results were used to improve the learning process at the next meeting. The test administered was a test of students' mathematical representation abilities.

Test results ability representation student in learning geometry are presented in Table 4.

Table 4. The result of students' representation ability test

Average value beginning	**Cycle I Average**	**Cycle II Average**	**N-Gain**
51	75	83	0,49

Based on Table 4, it shows that the average value beginning is 51 , the average value of cycle I is 75, and the average value of cycle I is 75 Cycle II 83. Next, the N-Gain score calculation was carried out, and the result was 0.4 7 or a moderate category. This indicates that the application of GeoGebra-assisted PBL learning in basic geometry courses is quite effective in improving students' representational abilities. Improvements happen because of the existence of repair in implementation learning in cycle II, which becomes a recommendation based on results evaluation Cycle I. Improvements that have been made include lecturers give questions guide during student do activities in PBL. This is in line with research suggestions from Anwar and Rahmawati (2024) that lecturers can ask open questions that stimulate discussion and encourage student activity. And according to the research results of Bouwer and Dirkx (2023) that help lecturers at the PBL stage help students develop ability representation. Strengthened with the use of GeoGebra will help visualize patterns and geometry, so that capable increase the ability to represent.

Every PBL stages encourage students to develop their representation ability on solving the problem. This is in line with Toth et al. (2000), multiple representation developed during the breaking process problem. At this stage, orientation problems, students identify the problem, which will push student capable convert data/information from a representation into the form of a diagram, graph, or table on the problem being solved. The identification process problem will form a scheme representation beginning (Gupta & Kaushik, 2022), where level involvement beginning will determine complexity

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representation (Thacker, 2023). Furthermore, the existence of organizing on PBL will contribute in push student capable of making mathematical models as a strategy for solving problems by involving mathematical expressions. Stages organized will push student do manufacturing connection between draft for enrich knowledge (Li & Bus, 2023), so that capable create a solution strategy that is presented in mathematical models. More next stage investigation will push student do testing solution through an experiment. The impact of students capable of drawing geometric patterns, explaining the steps to solve math problems with words, and solving them with mathematical expressions. The generalization process pattern geometric during investigation will contribute to developing a mathematical representation. In line opinion (Liu & Takeuchi, 2023) exploration pattern through investigation will optimize the translation problem to form equality mathematics. While at the stage presentation results, students do conveying complex ideas to in forms that can communicated For get bait back. As per the results of the study (Kramarski & Heaysman, 2021), the presentation results on PBL carried out testing validity to get bait come back to the problem. so that the push student is capable.

Research results show there is an improvement in the ability to achieve a significant, but not yet maximum, result. Increase happen because existence repair in the implementation of learning in cycle II, which becomes a recommendation based on the results evaluation of cycle I. Therefore, there is still potential for further development in the design or implementation of learning. so that the results are more optimal.

CONCLUSION

Integration of Problem-Based Learning and GeoGebra has been shown to improve students' mathematical representation skills. The combination of contextual learning methods and interactive visual aids encourages students to be more active and skilled in communicating mathematical ideas in various form representation. The implication of this research is the importance for lecturers to integrate learning technologies such as GeoGebra into innovative approaches such as PBL to improve the quality of mathematics learning in higher education. Upgrade Pen ability representation obtained in the category medium, for that need to study advanced. For more optimal results. The results of this study recommend that the implementation of GeoGebra-assisted PBL be carried out more systematically and sustainably, by designing authentic and challenging problems, especially ill-structured problems, to be able to trigger the emergence of various forms of mathematical representations of students. In addition, optimizing the use of GeoGebra features, not only as a visualization tool, but also as a means of independent exploration and construction of concepts. Likewise, strengthening the role of lecturers as facilitators, who actively guide the process of discussion, reflection, and translation between representations.

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