ISSN 2303-0992
ISSN online 2621-3176
Matematika dan Pembelajaran
Volume 13, No. 1, June 2025, h. 64-84
Submitted: January 2, 2025; **Revised**: April 26, 2025; **Accepted**: June 23, 2025

ENHANCING MATHEMATICAL LITERACY THROUGH GEOGEBRA CLASSROOM-ASSISTED LEARNING: A CASE STUDY IN INDONESIAN SECONDARY SCHOOLS

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Abstrak

Literasi matematis penting untuk membantu siswa menyelesaikan masalah nyata melalui penalaran matematika. Namun, siswa di Indonesia masih menunjukkan kinerja rendah dalam aspek ini. Penelitian ini bertujuan untuk mengkaji efektivitas pembelajaran berbantuan GeoGebra Classroom dalam meningkatkan literasi matematis siswa kelas VIII pada materi bilangan berpangkat dan akar. Dengan metode deskriptif kualitatif, data dikumpulkan dari 22 siswa melalui tes tertulis, kuesioner, dan wawancara. Hasil menunjukkan bahwa GeoGebra Classroom membantu pemahaman konsep, visualisasi materi abstrak, serta meningkatkan motivasi dan keterlibatan siswa. Penggunaan teknologi interaktif ini berdampak positif pada semua indikator literasi matematis, Temuan ini menunjukkan bahwa GeoGebra Classroom merupakan alat yang efektif untuk meningkatkan literasi matematis, dan disarankan dilakukan penelitian lanjutan dengan sampel yang lebih besar dan beragam untuk memperkuat dan memperluas temuan.

Kata kunci: Kelas GeoGebra; Literasi Matematis; Pembelajaran Digital; Matematika Sekolah Menengah; Pembelajaran Berbantuan Teknologi.

Abstract

Mathematical literacy is important for helping students solve real-world problems through mathematical reasoning. However, students in Indonesia still demonstrate low performance in this area. This study aims to examine the effectiveness of GeoGebra Classroom-assisted learning in improving the mathematical literacy of eighth-grade students on the topic of exponents and roots. Using a qualitative descriptive method, data were collected from 22 students through written tests, questionnaires, and interviews. The results showed that GeoGebra Classroom supported conceptual understanding, improved visualization of abstract material, and increased student motivation and engagement. The use of this interactive technology had a positive impact on all indicators of mathematical literacy. These findings suggest that GeoGebra Classroom is an effective tool for enhancing mathematical literacy, and further research with larger and more diverse samples is recommended to strengthen and expand upon these results.

Keywords: Geogebra Classroom; Mathematical Literacy; Digital Learning; Secondary Mathematics; Technology-Assisted Instruction

Citation: Raisatunnisa., Suryadi, D., Fatimah, S., Priatna, N., Nasir, N. 2025. Enhancing Mathematical Literacy Through Geogebra Classroom-Assisted Learning: A Case Study In Indonesian Secondary Schools. *Matematika dan Pembelajaran*, 13(1), 64-214. DOI: http://dx.doi.org/10.33477/mp.v13i1.8938

INTRODUCTION

Mathematical literacy is recognized as a core component of contemporary education, providing students with the ability to interpret, analyze, and apply mathematical knowledge in diverse contexts (Susanta et al., 2023). This skill is especially essential in implementing curriculum frameworks that emphasize contextual and real-life problem-solving (Putri & Juandi, 2024).Mathematical literacy has become a major focus of education in many countries, driven by the growing global demand for individuals who are prepared to meet the challenges of the 21st century. This competency involves understanding, applying, and reasoning with mathematical information in real-world contexts skills essential for informed decision-making in everyday life (Maryani & Widjajanti, 2020;Rojas & Benakli, 2020) In Indonesia, mathematical literacy remains a challenge, as reflected in the low performance on both national and international assessments. It not only supports higher-order thinking skills but is also closely linked to students' self-confidence in learning mathematics (Nurwahid & Ashar, 2022; Pratama, 2020). Therefore, this study focuses on efforts to enhance mathematical literacy as a key objective of mathematics education in schools (Ekawati et al., 2020; Sopiany et al., 2022).

Despite efforts to improve mathematical literacy, students in Indonesia continue to demonstrate low levels of skills at all levels of education. Weak mathematical literacy remains a barrier to achieving broader goals in mathematics education. Research shows that students from elementary to university levels struggle with literacy, and different learning styles affect their performance (Aisyah & Juandi, 2022)

International studies and assessments have also highlighted the low levels of mathematical literacy among Indonesian students. For example, Stacey (2011) noted that many Indonesian secondary school students struggle in the early stages of solving PISA problems. They often find it difficult to understand problems and translate word problems into appropriate mathematical representations. This is supported by data from the Programme for International Student Assessment (PISA), which shows a consistent decline in scores. Indonesia's score dropped from 386 in 2015 to 379 in 2018, and further to 366 in 2022 (OECD, 2023). In the 2022 report, more than 80% of Indonesian students were classified as low achievers in mathematical literacy.

Various factors can cause the low mathematical literacy of Indonesian students. First and foremost, research has highlighted the gap between the learning approaches used in the classroom and the real-world applications of mathematics that are critical to developing mathematical literacy (Rusdi et al., 2018; Nurwahid & Ashar, 2022)Herefore, more people in the world need better literacy skills to be able to find, select, interpret, analyze and produce information that is relevant to them (Kolinksy et al., 2022; Shashikala A K, 2023;Genlott & Grönlund, 2016) This suggests that a more holistic and targeted approach, which addresses pedagogical practices and assessment frameworks, is needed to address the persistent barriers to improving mathematical literacy in the Indonesian education system.

One approach that is considered effective in improving mathematical literacy is through the integration of digital technology in mathematics learning (Novita & Herman, 2021). The use of technology not only facilitates access to information but can also help students understand abstract concepts through interactive visualization. In this context, students' ability to build connections between mathematical concepts and their applications in real life can be improved through the support of digital media.

One technology that is widely used and proven to support the mathematical visualization process is GeoGebra. GeoGebra is dynamic mathematics software that combines geometry, algebra, and calculus in one easily accessible platform. This application allows students to manipulate mathematical objects directly, so that they can understand concepts more concretely and visually (Mathias, 2023; Schreiberova & Morávková, 2023). Several studies have also shown that the use of GeoGebra in learning can improve students' conceptual understanding and interest in learning mathematics (Alkhateeb & Al-Duwairi, 2019.

In line with that, GeoGebra has proven to be a valuable asset in mathematics education, promoting active learning and developing 21st-century skills(Anggreini et al., 2023; Diva et al., 2023) and is an effective tool to support and is an effective tool to support and improve the mathematical representation abilities of junior high school students(Batiibwe, 2024;Nuraeni et al., 2021) Geogebra Classroom, a dynamic mathematics software, has been shown to improve mathematical literacy (Yerizon et al., 2021).

In recent years, technology has become a handy tool to change how teachers teach and students learn. One form of digital technology advancement in mathematics education is the development of GeoGebra Classroom, an interactive software that integrates various fields of mathematics such as algebra, geometry, calculus, and statistics into a single, unified platform. More than just a visualization tool, GeoGebra Classroom is designed to foster an active, collaborative, and real-time problem-solving learning environment. This approach aligns with constructivist theory, which emphasizes the importance of active student engagement in constructing their own knowledge through interaction with mathematical concepts and learning contexts (Rosyidi et al., 2024).

Building on this foundation, GeoGebra Classroom empowers teachers to design interactive lessons and assessments that actively involve students in the learning process. This not only increases student engagement but also enhances their conceptual understanding and encourages meaningful application of mathematical concepts (Zöchbauer et al., 2021). In addition, GeoGebra Classroom has been shown to improve students' understanding and enhance their learning experience (Tamam & Dasari, 2021; Zilinskiene & Demirbilek, 2015). Using

Geogebra Classroom has become an innovative solution for improving students' mathematical literacy.

Geogebra Classroom is a free application that can be accessed online or offline. It provides various features that allow students to learn geometry and algebra simultaneously. Geogebra Classroom features enable collaborative learning interactions, simulations, animations, and dynamics directly and interactively. Through this virtual platform, teachers can give interactive and engaging assignments to students, monitor the progress of students' work, ask questions to all students and see the answers quickly, and facilitate rich and interactive discussions among all students, groups of students, and even individual students. In addition, this platform also allows mathematics teachers to collaborate with fellow mathematics teachers in the same school and between schools. Thus, this platform aligns with the goal of meaningful mathematics learning.

This study aims to explore the effectiveness of Geogebra Classroom in enhancing the mathematical literacy of Indonesian secondary school students. It focuses on how this dynamic software supports students in understanding, applying, and analyzing mathematical concepts in real-life contexts. Through well-designed Geogebra-based lessons, the study examines its impact on students' problem-solving, data interpretation, and mathematical communication. It also investigates students' attitudes toward the tool and the challenges faced during its implementation. The findings are expected to offer valuable insights for educators and policymakers in advancing mathematics education through digital technology.

METHOD

This study employs a descriptive method with a qualitative approach, which is deemed appropriate for exploring in-depth insights into students' experiences, perceptions, and learning processes related to mathematical literacy. The qualitative approach allows for a rich, contextual understanding of phenomena as they occur naturally, aligning with the interpretivist paradigm that emphasizes meaning-making from participants' perspectives. Through this method, the study aims to capture complex interactions and learning behaviors that may not be easily quantifiable through statistical analysis alone(Creswell, 2014). This study describes learning using the Geogebra Classroom in building mathematical literacy skills. A qualitative approach was chosen because it allows researchers to dig deeper into information, understand students' experiences and perspectives, and see phenomena in a broader context without being limited by numbers or statistics.

The participants consisted of 22 eighth-grade students selected through purposive sampling based on specific criteria: they were currently studying the topic of exponents and roots and had prior experience with GeoGebra Classroom-based learning. The main criteria for selecting participants were grade VIII students, because the material studied, namely exponents and roots, is part of the curriculum taught at this level. In addition, the selected students must also have experience using GeoGebra Classroom in mathematics learning, especially related to the material that is the focus of the study.

Data collection techniques in this study include written tests, questionnaires, and interviews. Written tests are used to obtain quantitative data related to students' mastery of mathematical concepts objectively and measurably. In addition, a questionnaire distributed via Google Form was used to obtain quantitative data related to students' perceptions of learning assisted by GeoGebra Classroom. To explore learning experiences and the use of GeoGebra Classroom in solving mathematical problems and developing mathematical literacy, a questionnaire consisting of 15 questions and interviews with three selected students were employed.

This interview technique provides deeper qualitative insights, allowing researchers to understand students' thinking processes and how they apply mathematical concepts in real contexts. Data were analyzed using the Miles and Huberman (1994) framework, which involves three concurrent flows of activity: data reduction, data display, and conclusion drawing. This method facilitated a systematic interpretation of students' responses from tests, interviews, and questionnaires.

RESULT AND DISCUSSION

The use of Brunner's theory in Utilising GeoGebra Classroom on power numbers

- Enactive Stage

In this activity, students are given a story problem about the development of bacteria in the human body. The problem explains that bacteria multiply by dividing into two every hour. Students are asked to describe the development of bacteria until the third hour on the activity sheet in GeoGebra Classroom. In this activity, students can use various tools provided, such as pens, rulers, erasers, and other tool

Figure 1. Student Worksheets In Geogebra Classroom For Enactive Stage

The results of the students' work showed that most of them were able to describe the process of bacterial reproduction sequentially starting from 1 to 2, then 4, and up to 8 bacteria by the third hour. In addition to drawing, they also wrote down the multiplication pattern, such as $1 \times 2 \times 2 \times 2 = 8$, which indicates an initial understanding of the concept of exponents. This activity demonstrates that the students were not merely following instructions, but were also beginning to develop an understanding through visual and concrete representations

- Iconic Stage

At this stage students use information on Geogebra Classroom activities where the activities provided can form new information based on internal thoughts. Knowledge is presented by activities that represent a concept but still need to fully define the concept

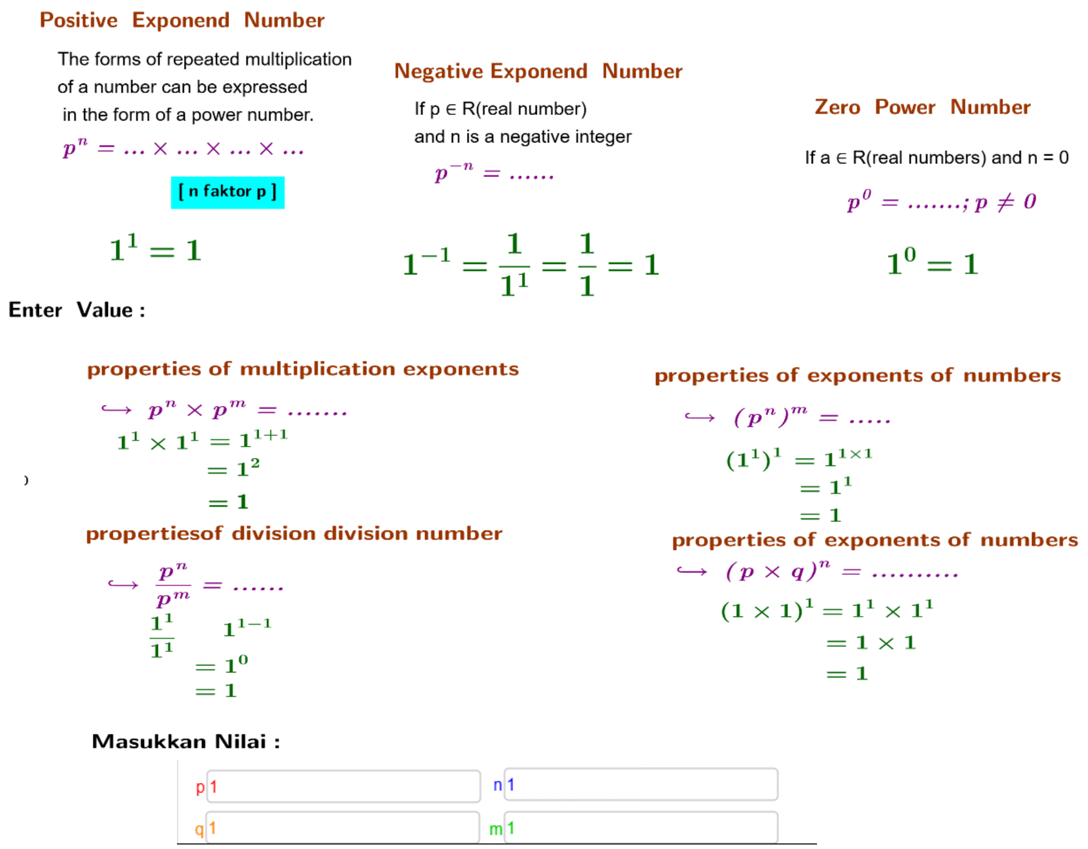


Figure 2. Student Worksheets In Geogebra Classroom Iconic Stage

At this stage, students show the ability to conclude various exponent rules—from positive, negative, and zero exponents to multiplication and division properties. They don't merely memorize formulas but begin to build conceptual understanding through exploration, identifying patterns such as $p^n \times p^m = p^{n+m}$ or $\frac{p^n}{p^m} = p^{n-m}$. This indicates growing abstract thinking and the ability to generalize independently.

Cognitively, students are transitioning from Piaget's concrete operational stage to the formal operational stage. They start manipulating symbols without relying on visuals and demonstrate reflective thinking. This activity not only assesses learning outcomes but also reveals their evolving thinking processes through active engagement with mathematical concepts.

- Symbolic Stage

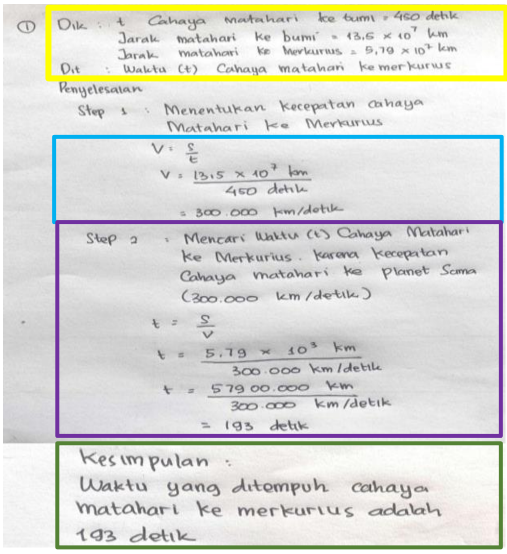
Students work on several problems to answer the questions in the Geogebra Classroom activity by using the multiplication operation and applying the properties of power numbers that students have found in the previous activity

Mathematical Literacy Ability of Geogebra-Assisted Students

The following are questions and interview analyses of three students concerning mathematical literacy indicators: communication, mathematisation, problem-solving strategies, representation, using operations, symbol technique language and formal reasoning

- Mathematical Literacy of Subject S1

The following are the results of the work and interviews of subject S1 in solving the problem of power numbers.



Given : speed of sunlight to Mercury = 450 second
Distance from sun to Marcury = 13,5 x 10^7 km
Distance from sun to Earth = 5,79 x 10^7 km
Calculate the travel time of sunlight to Marcury

Step 1 : Determine the speed of sunlight to Mercury

$$v = \frac{s}{t}$$

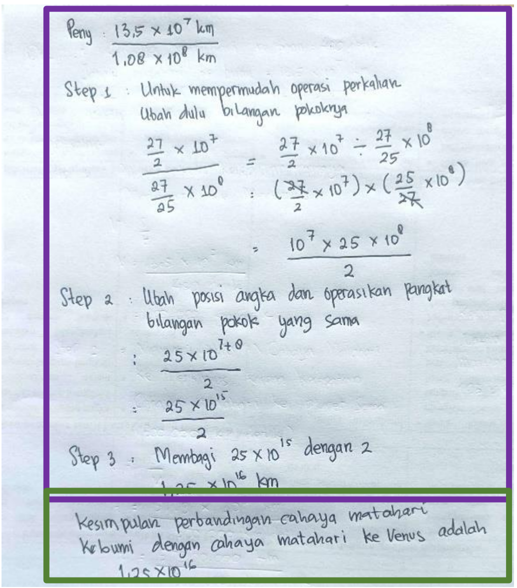
$$v = \frac{13{,}5 \times 10^7 \text{ km}}{450 \text{ second}} = 300.000 \text{ km/s}$$

Step 2 : To calculate the time (t) it takes for sunlight to reach Mercury, assuming the speed of light from the Sun to the planet is the same, which is 300,000 km/s

$$t = \frac{s}{v}$$

$$v = \frac{5{,}79 \times 10^7 \text{ km}}{300{,}000 \text{ km/s}} = \frac{57900.000 \text{ km}}{300{,}000 \text{ km/s}} = 193 \text{ s}$$

The conclusion is that the time it takes for sunlight to reach



answer $\frac{13,5 \times 107 \text{ km}}{1,08 \times 107 \text{ km}}$

Step 1 To simplify the operation, first change the base number.

$$v = \frac{\frac{27}{2} \times 10^7}{\frac{27}{25} \times 10^8} = \frac{27}{2} \times 10^7 : \frac{27}{25} \times 10^8$$

$$= \frac{27}{2} \times 10^7 : \frac{25}{27} \times 10^8$$

$$= \frac{10^7 \times 25 \times 10^8}{2}$$

step 2 : Rearrange the numbers and operate the exponents with the same base

$$\frac{25 \times 10^{7+8}}{2}$$

$$\frac{25 \times 10^{15}}{2}$$

step 2 : Devide 25×10^{15} with $2 = 1,25 \times 10^{16}$ *km*

The conclusion of the comparison between the sunlight reaching Earth and the sunlight reaching Venus is $1,25 \times 10^{16}$ *km*

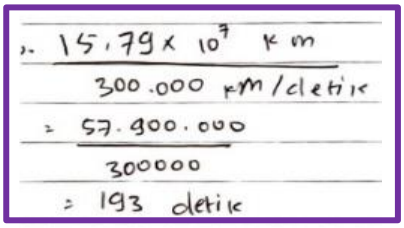
Figure 3. Result of Subject S1's Work

- Outlining known and questioned information
- Write down the initial strategy used
- Elaborate the solution steps appropriately
- Describe the answer and conclusion appropriately

Figure 3 shows that subject S1 can write down all the information known and asked in the problem and convert information into mathematical information. The subject can also write and explain the strategy used correctly, and subject S1 explains the conclusions obtained. Students express their reason for justifying the results of student answers by checking the answers they did before.

- Mathematical Literacy of Subject S2

The following are the results of the work and interviews of subject S2 in solving the problem of power numbers.



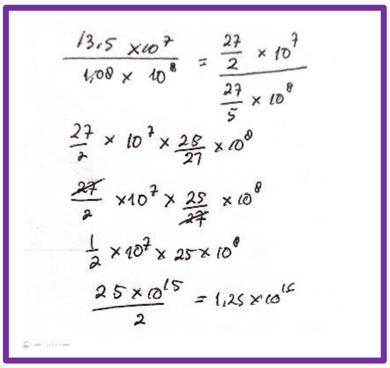


Figure 4. Result of Subject S2's Work

Elaborate the solution steps appropriately

Figure 4 indicates that subject S2 did not fully write down the known and asked-for information. However, the interview revealed that the subject understood the problem's context and was able to identify its key elements. The subject also demonstrated the ability to translate contextual information into mathematical representations, explain solution strategies, and articulate conclusions logically. This reflects mathematical literacy skills, particularly in interpreting information, formulating problems, and verbally communicating understanding, even though written representations remain limited

- Mathematical Literacy of Subject S3

The following are the results of the work and interviews of subject S3 in solving the problem of power numbers.

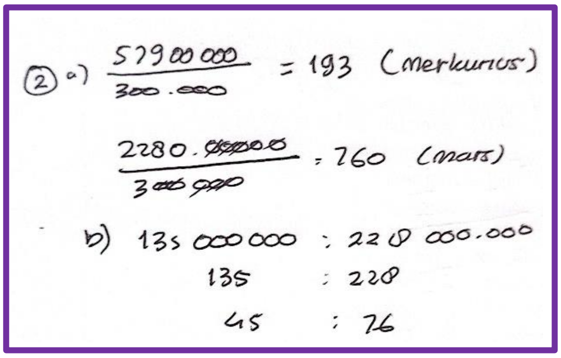


Figure 5. Result of Subject S3's Work

Elaborate the solution steps appropriately

Figure 5 shows that subject S3 did not write down all the information known and asked, but at the time of the interview, subject S3 was able to explain what was asked and known; the subject was also able to explain the strategy used, convert information into mathematical information, subject S2 was also able to explain the conclusions obtained

Learners' Perspectives Regarding the Utilisation of Geogebra Classroom

The description of the data from this study provides an overview of student answers to questionnaires distributed to students to determine students' mathematical literacy skills in Geogebra Classroom-based learning. The questionnaire design consists of 18 statements, which are divided into six aspects, namely: (1) Communication, (2) Mathematical, (3) Problem-solving strategies, (4) Representation, (5) Technical language symbols and formal and (6) Reasoning reasoning.

The results of the analysis carried out on each aspect of the mathematical literacy level are as follows:

- Communication

Communication relates to an individual's point of view about the Geogebra Classroom application. The results of the questionnaire analysis for communication indicators can be seen in Figure 7

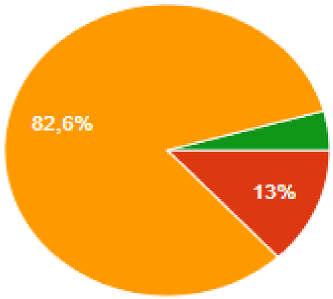


Figure 6. Overview Communication Aspect

The high percentage of respondents who agreed and strongly agreed (86.9%) indicates that GeoGebra Classroom is perceived as effective in supporting communication in mathematics learning. This perception is further reinforced by the results of questionnaires and interviews, which reveal that the application's interactive features and visual design facilitate the exchange of ideas and the understanding of concepts, particularly in topics such as exponents and root.

From the perspective of constructivist theory, communication among students and between students and teachers is an integral component of the knowledge construction process. Accordingly, these findings suggest that GeoGebra Classroom is not only positively received but also functions as a medium that promotes meaningful learning through social interaction and conceptual exploration. This conclusion aligns with previous studies (Magfirah et al., 2021; (Jelatu et al., 2018; Ocal, 2017; Zulnaidi & Zakaria, 2012), which affirm GeoGebra's contribution to enhancing students' communication skills and mathematical understanding.

- Mathematical

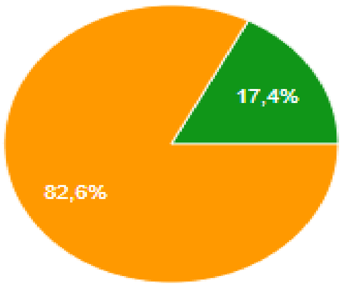


Figure 7. Overview Mathematical Aspect

The figure shows that the percentage of agreed is 82.6%, and strongly agreed is 17.4%. The information obtained from this results of questionnaires and interviews with subjects is that Geogebra Classroom Geogebra Classroom helps students find the mathematics concept of power and root numbers more easily. Learning using GeoGebra can increase enthusiasm, self-confidence, and motivation and make students able to think critically and creatively (Arbain & Shukor, 2015)

- Problem Solving Strategy

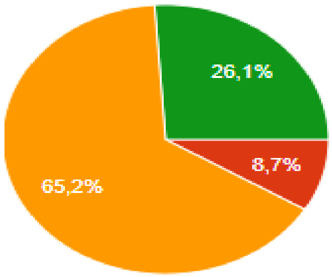


Figure 8. Overview Problem Solving Strategy Aspect

Figure 8 shows that the majority of respondents (91.3%) agreed or strongly agreed that GeoGebra Classroom assists in designing and implementing mathematical problem-solving strategies, while only 8.7% disagreed. Findings from the questionnaires and interviews indicate that students felt supported in identifying solution steps and understanding the relationships between concepts through GeoGebra's interactive features.

Within the framework of constructivist theory, problem-solving strategies are a crucial component of the learning process, which emphasizes students' active engagement in constructing their own knowledge. GeoGebra Classroom, with its ability to present visual representations and enable direct manipulation of mathematical objects, encourages students to explore various approaches and reflect on the solutions they develop. Therefore, the application not only supports technical proficiency in solving mathematical problems but also reinforces the critical and reflective thinking processes essential to meaningful learning.

- Representation

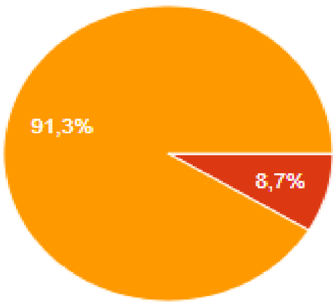


Figure 9. Overview Representation Aspect

In Figure 9, it can be seen that the percentage of agreed is 91.3%, and disagreed is 8.7%. Information obtained from the results of questionnaires and interviews with subjects is Geogebra Classroom. As many as 91.3% of students agree that the material presented using Geogebra is shorter and easier to understand so that they can create problem situations based on the data or representations given. Students are helped to understand the material using Geogebra Classroom and compile problem-solving steps.

- Technical language symbols and formal

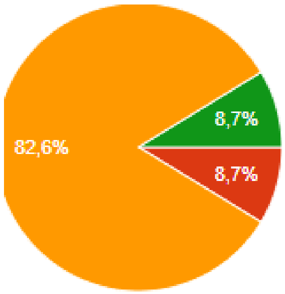


Figure 10. Overview Technical Language Aspects of Symbols and Formal Aspect

Figure 10 shows that the majority of respondents (82.6%) agree that GeoGebra Classroom facilitates the use of arithmetic operations in the topic of exponents and roots, particularly in relation to the technical language of symbols and the formal aspects of mathematics. The findings from questionnaires and interviews support this data, with students reporting that the clear visual display and interactive features of GeoGebra assist them in understanding and applying mathematical symbols and operations more effectively.

From the perspective of constructivist theory, learning experiences that involve visual representations and direct interaction with mathematical objects enable students to actively construct understanding through processes of exploration, reflection, and conceptual connection. Thus, GeoGebra Classroom not only facilitates the use of mathematical symbols but also serves as a medium that supports meaningful learning through independent and contextual knowledge construction

- Giving reasons for reasoning

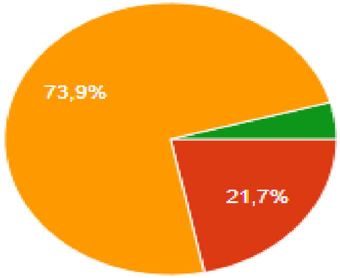


Figure 11. Overview Giving Reasons For Reasoning Aspect

Figure 11 shows that 78.2% of respondents agreed or strongly agreed that GeoGebra Classroom supports students in justifying their answers by re-examining their work. Questionnaire and interview results confirm that features such as re-visualization and step manipulation help students review their reasoning and evaluate answers independently. In line with constructivist theory, this reflective process is essential to developing mathematical reasoning. Thus, GeoGebra Classroom functions not only as a technical aid but also as a tool that fosters deeper understanding through active exploration and reflection.

Discussion

The use of the Geogebra Classroom application has been proven to help students understand mathematical concepts and procedures, particularly in topics involving integers and roots. Based on student work, interviews, and questionnaires, all indicators of mathematical literacy were fulfilled. This supports previous research (Zulnaidi & Zakaria, 2012) which found that Geogebra Classroom enhances both conceptual and procedural knowledge. Additionally, the application helps students visualize abstract mathematical concepts in a more concrete way (Hayati & Ulya, 2022; Hamzah & Hidayat, 2022), while promoting active and collaborative interactions between teachers and students (Shadaan & Leong, 2013). This dynamic interaction encourages students to be more engaged and confident in solving mathematical problems.

These findings highlight the significant impact of integrating Geogebra Classroom into mathematics instruction in enhancing students' mathematical literacy. The software's dynamic and interactive features assist students in understanding and applying abstract concepts within real-world problem-solving contexts. Improvements in both conceptual and procedural understanding, along with increased motivation and confidence, indicate that a technology-assisted approach not only strengthens mathematical comprehension but also supports students' problem-solving skills and self-efficacy. Thus, Geogebra Classroom plays a crucial role in building a strong foundation for mathematical literacy.

CONCLUSION

GeoGebra Classroom has been proven to be an effective mathematics learning tool. Its use offers significant advantages in the teaching and learning process, such as allowing educators to develop more engaging and interactive materials, which can enhance students' motivation and interest in mathematics. Additionally, GeoGebra Classroom helps students understand mathematical concepts through interactive visualization and manipulation, particularly in exponents and roots, which are often considered abstract.

The results of the study showed that GeoGebra Classroom met all the indicators of mathematical literacy in exponents and roots, including communication, mathematization, problem-solving, representation, the use of operations, symbols, and reasoning. Thus, GeoGebra Classroom is effective in improving students' conceptual understanding and mathematical literacy skills.

However, this study has limitations, such as a sample size limited to 22 students and a focus on exponents and roots. Therefore, further research is needed with a larger sample size and across various levels of education. Research could also compare GeoGebra Classroom with other teaching methods to identify factors influencing its success, such as students' technological skills and teacher read.

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