

Promoting mathematics problem solving ability through implementing GeoGebra- assisted problem based learning

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Promoting mathematics problem solving ability through implementing GeoGebra-assisted problem based learning

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Abstract: One of the skills necessary for 21st-century society is the capacity for problem-solving. Students will be required to work in unfamiliar settings, solve problems they have never faced before, and use skills unrelated to any particular subject matter. GeoGebra is a learning environment that provides a variety of representations and simulates various mathematical models. This article aims to describe instructions for the use of Geogebra-assisted PBL in promoting students' capacity for problem-solving. The students who participated in this study consisted of 36 high school students. Mathematics learning is done using the GeoGebra application during the learning process. The method used in this research is descriptive analysis and qualitative research. The specific technique used in implementing GeoGebra-Assisted Problem Based Learning is students through two phases in each sub material. The first phase is focusing on the problems that lead to an understanding about representation for solutions and not solutions in inequality and inequality system. The second phase is focusing on the real world problems that lead to an understanding solving problems using GeoGebra. The results of the study show that teachers need to develop student exploration processes through representations, simulations, problems, and solutions using GeoGebra that are close to student reality. The use of GeoGebra-assisted PBL is mathematics learning is able to support student exploration so that students are more involved in the learning process by paying attention to student interaction and exploration. The use of GeoGebra makes students active knowledge builders, tracks the process of change, and keeps students engaged with teachers in mathematics teaching. The analysis carried out was supported by student learning outcomes, which showed that the average learning outcomes were significantly different and exceeded the Minimum Criteria of Mastery Learning and as many as 86% of students scored above the Minimum Criteria of Mastery Learning. The use of GeoGebra-assisted PBL considerably increased students' capacity for problem-solving, notably in terms of their capacity to recognize issues, obtain data, evaluate it, and suggest solutions. Additionally, students perceived that GeoGebra was a useful tool for accelerating their learning, offering dynamic and interesting learning opportunities, and strengthening their capacity for problem-solving.

Keywords: GeoGebra; Mathematics problem solving ability; Problem-based learning

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INTRODUCTION

The use of technology in learning enables students to take an active role in the teaching-learning process by enabling them to explore and understand mathematical concepts through direct interaction with digital resources and software specifically designed for this purpose. It



also allows students to study at their own pace by allowing them to access and repeat material that is difficult for them to understand. Access to digital technology and the frequency of its use in the classroom have increased. The use of information and communication technology in learning can promote student-centered learning (Murthy et al., 2017). However, it is important to note that the use of technology in learning cannot substitute for social interaction and physical activity, which are important in the teaching-learning process. Therefore, it is important to find the right balance between the use of technology and direct interaction between students and teachers, as well as between students and each other.

According to Csapó and Funke's (2017) study, problem-solving abilities are one of the skills required for modern society in the twenty-first century. With these skills, students will be expected to work in new environments, encounter problems they have never encountered before, and apply abilities that are not tied to specific content. Problem solving in the real world refers to situations that require decision making in the context of work or managing personal life and all of this is expected to be maximized through learning at school. In order to learn mathematics according to the accepted principles of school mathematics, students must develop their problem-solving skills (NCTM 2000).

Student-centered learning focuses on the active construction of students' knowledge and understanding (Baeten et al., 2013; Ke and Kwak 2013; Neumann 2013). The use of ICT also allows teachers to more easily adapt learning to the individual needs of students and facilitates student-centered learning. By using various software and applications, teachers can create more interactive and engaging learning experiences, which can help motivate students and increase their participation in the teaching-learning process. Student-centered learning is learning that makes students the focal point of the learning process, actively participating in class to achieve learning goals and academic results (Zain et al., 2012).

Student-centered learning also allows students to learn through exploration and experimentation so that they can find for themselves the best way to solve problems and face challenges in mathematics. In this process, students can also develop the ability to make decisions, innovate, and think creatively. Student-centered learning has the potential to enhance student learning experiences, and students are encouraged to explore mathematical concepts independently or in groups (Levesque-Bristol 2023).

Both the degree of students' mathematical proficiency and their grasp of scientific concepts have improved thanks to modern technology, especially educational technological applications (Alabdulaziz et al. 2021). Students can design numerous representations, both internal and external, using GeoGebra. The terms "internal representation" and "external representation" describe two different ways that pupils convey their grasp of mathematical concepts: internally and externally. Students can design several visual representations of a mathematical subject in GeoGebra, including charts, tables, and equations. Students can create various representations both internally and outwardly using GeoGebra, according to cognitive research and pedagogical consequences (Bu and Schoen, 2011s).

The goal of integrating technology into math instruction is to improve student technology use while also increasing math learning. GeoGebra is a math learning software designed to help students understand math concepts more easily and interactively. This software is very popular among mathematics researchers and educators because it has the potential to revolutionize the teaching and learning of mathematics. One of the main advantages of using GeoGebra in learning mathematics is the ability of students to describe geometric objects quickly and precisely. This allows students to visualize math concepts in a clearer and easier-to-understand way. Apart from that, GeoGebra also features a Computer Algebra System (CAS), which allows students to solve equations and math problems more easily and efficiently. GeoGebra is dynamic geometry software that allows students to interactively change the shape and size of geometric objects. This helps students understand math concepts better, as they can see the effect of changes they make in the shape and size of objects created using mathematical equations or geometric objects. In addition, GeoGebra also allows students to draw graphs,

solve equations, and perform mathematical modeling in one easy-to-use application (Negara et al. 2022).

Students who are still not actively involved in the learning process, especially when doing independent exploration to understand the material. So, to make changes so that students are actively involved, and learning teachers must innovate in learning. One of them is in the material on the System of Two Variable Linear Inequalities in class X, where the teacher carries out learning using GeoGebra.

METHOD

Descriptive analysis is the method of research used in this article. In qualitative research, descriptive analysis uses content analysis techniques, which involve locating and classifying textual or other data's information into distinct categories or themes (Creswell 2018). The implementation of learning takes place in senior high school through descriptive analysis through observation and documentation studies. A combination of observation and documentation studies were done to assess the efficiency of the GeoGebra-assisted PBL technique. During class, the observation component includes rigorous monitoring of students' interactions, problem-solving processes, and involvement with GeoGebra. These observations were conducted in real time, providing direct insights into the learning experiences of students. Predefined categories and indicators were used in these protocols to capture key elements of student behavior, such as cooperation, problem-solving tactics, and use of GeoGebra's interactive features. To support the observational data, documentation analysis was used in addition to real-time observations. Documents of various forms, including student work samples, written reflections, and outputs produced during GeoGebra-assisted PBL activities, were gathered and examined. Purposive sampling was used to pick these documents, with the goal of representing a cross-section of student performance and growth. The researchers took a methodical approach to document analysis, including qualitative methodologies to find repeating patterns and insights connected to students' mathematical comprehension and problem-solving abilities. They examined the papers thoroughly and classified the data in order to unearth valuable information and capture the intricacies of student learning inside the GeoGebra-assisted PBL method. The study was limited to be performed at SMA N 2 Semarang, an urban school with students aged 15 to 17, most students come from middle-class backgrounds, 36 students in class X participated in this study. The data obtained are determined using a descriptive research methodology. Write a brief description of the GeoGebra application first. The first step is the planning stage, where the goal is to identify the formulation of the issues discovered during the in-class learning process. Finding several alternative solutions that address the problem formulation is the second stage of implementation. The third stage is analysis and conclusion.

RESULTS AND DISCUSSION

In the mathematics lesson that was conducted in class X senior high school in Semarang, the teacher taught using GeoGebra on the material System of Two Variable Linear Inequalities. The specifically parts of problem-solving that were measured were mathematical reasoning, problem formulation, strategizing, and mathematical modelling. These abilities were assessed to determine the students' ability to apply mathematical principles and approaches to solving problems in real-world circumstances. The learning that is carried out begins by inviting students to understand the learning that will be carried out and the results that will be achieved after carrying out the learning. To build a positive environment from the start of learning, students need to know the goals and expectations of the learning that is carried out (Casazza & Silverman, 1996). The learning that is carried out begins by inviting students to understand the learning that will be carried out and the results that will be achieved after carrying out the learning. To build a positive environment from the start of learning, students need to know the

goals and expectations of the learning that is carried out (Casazza and Silverman, 1996). Before learning to use GeoGebra, students are invited to get to know GeoGebra better and be prepared for learning a system of two-variable linear inequalities. Figure 1 is the process for implementing GeoGebra-assisted problem solving in mathematics learning activities.

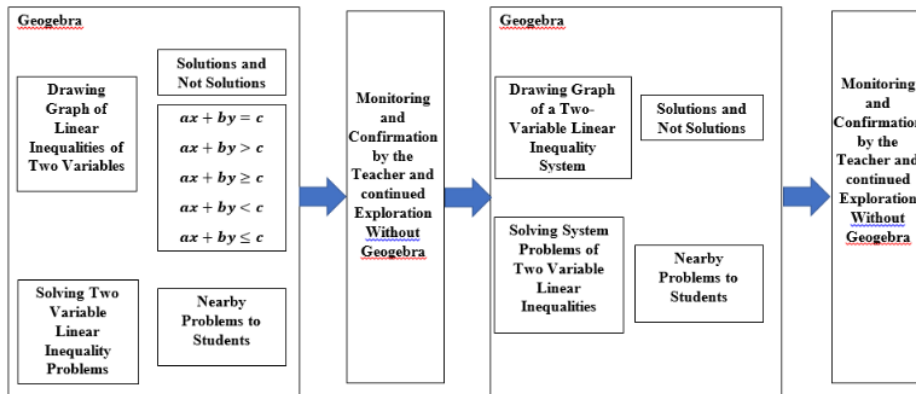


Figure 1. Learning Process in GeoGebra-Assisted Problem Solving

Activities At the first meeting, the teacher gives instructions for what the students will do. The teacher provides instructions for learning material about what a linear inequality of two variables is, makes a graph of it, and determines the solution area of a linear inequality of two variables using GeoGebra. Students are asked to understand the value of inequalities that fulfill more than or more than equal to, less than or less than equal to. All object in GeoGebra can be manipulated virtually. Mathematics concepts can be introduced or reinforced with the aid of virtual manipulative (Silverman and Hoyos, 2018). The first meeting created in GeoGebra is designed as in Figure 2.

Drawing Graph And Solving Inequality of Two Variable Problems

The first section you will learn to drawing graph and find the solutions and not the solutions of inequality of two variable

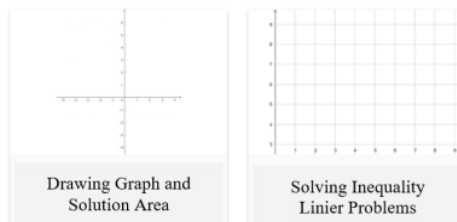


Figure 2. First meeting learning in GeoGebra

The process of using GeoGebra in mathematics learning can be done in several stages, namely drawing a graph of two-variable linear inequalities, solving problems that are close to students, and monitoring and confirmation by the teacher, followed by exploration without GeoGebra. In the process of graphing linear inequalities between two variables, GeoGebra can be used as a visualization tool. The use of GeoGebra in learning mathematics can help students visualize abstract mathematical concepts such as lines and fields (Tamam & Dasari 2021). Students can try to graph several linear inequalities and determine solutions and non-solutions by checking whether the area formed fulfills all linear inequalities. Learning using GeoGebra is designed so that students actively explore linear inequalities between two variables. This can help students strengthen their understanding of the concept of solutions and non-solutions.

Menggambar dan Daerah Penyelesaian Pertidaksamaan Dua Variabel

Auteur: muhammad98, M1 Algebra 1, Geometry, Algebra 2, GeoGebra Classroom Activities

Gunakan teknologi graph untuk membuat grafik wilayah solusi dari setiap pertidaksamaan dan membuat sketsa setiap grafik.

Sesuaikan jendela grafik sesuai kebutuhan untuk menampilkan informasi yang bermakna.

Anda dapat menggunakan applet di bawah atau kalkulator grafik di <https://www.geogebra.org/graphing>

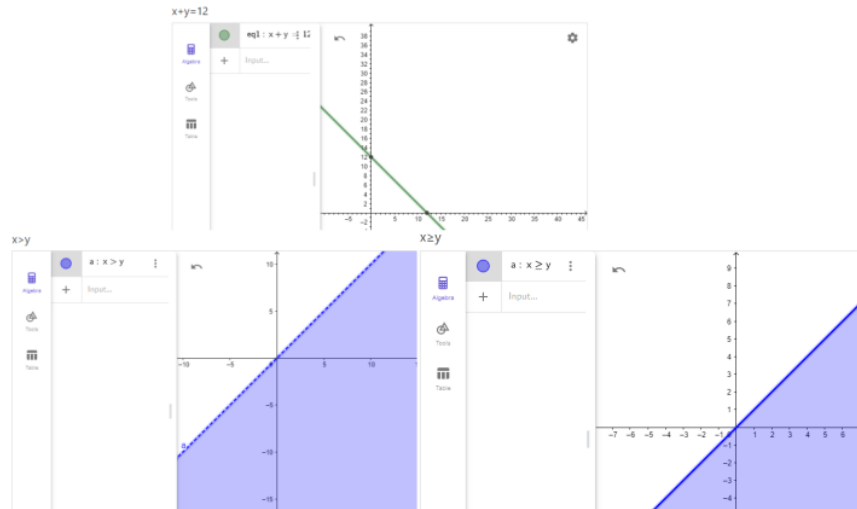


Figure 3. The results of the visualization image determine the settlement area in GeoGebra

After students understand the appropriate value of an inequality, the teacher gives further instructions, namely how to determine the area of completion of an inequality. The teacher presents an image of Cartesian coordinates and an inequality (see Figure 3); students are asked to find several pairs of coordinates that meet or do not satisfy the inequality by finding several pairs of numbers that represent solutions to the inequality and not solutions to the inequality. Students mark the coordinates of a point that is or is not a solution with a different color or sign. Students determine the point until they see an area that is a solution or not.

According to [Csapó and Funke \(2017\)](#), teaching students how to use representations, particularly multiple representations (for example, figurative and descriptive representations), and practicing transformations between representations can help students become more adept at solving problems. In addition, with GeoGebra, students can use multiple representation, in this study students use transformation from descriptive to figure for example the distinction between inequality $x > y$ and $x \geq y$ as shown in Figure 3.

Students' perceptions of the use of GeoGebra show that students accept and are satisfied, and it is concluded that the use of GeoGebra as being able to support student pedagogy and technology allows it to support mathematics learning, assisting students in gaining a deeper understanding of mathematical concepts ([Suárez et al., 2023](#)). By gaining a solid understanding of two-variable linear inequalities graphs, students can develop their skills in solving more complex mathematical problems.

In the second stage, students learn solve realistic problems that around the students' life for example buying some stuff with some amount of money as shown in Figure 4 by using GeoGebra. In Figure 4 the problem is about a children buy some stationery, he got some money in his pocket, the children should find maximum stationery that the children can afford. GeoGebra is an easy-to-use application, GeoGebra allows for discovery learning, GeoGebra encourages collaborative learning, and GeoGebra is for visualizing geometric transformations, GeoGebra is for visualizing geometric transformations ([Dahal et al. 2022](#)). Likewise, GeoGebra aids in the teaching and understanding of abstract transformation concepts. Students can solve these problems analytically and present their solutions. The problems presented are designed

to be close to students so that they can connect more with them. Learning mathematics needs to be close to student reality (Freudenthal 1977). Being connected to reality and relevant to students, its use in realistic problems is one of the determinants of mathematics education (Van Den Heuvel-Panhuizen 2003). After understanding the concepts needed by students to solve problems regarding linear inequalities of two variables, one of which is presented in Figure 4.

Disajikan sebuah situasi, silahkan jawab pertanyaan sesuai arahan yang diberikan.

1. Tulis pertidaksamaan untuk menjelaskan batasannya.
2. Tentukan apa yang diwakili oleh setiap variabel.
3. Gunakan teknologi grafik untuk menggambarkan pertidaksamaan.
4. Sebutkan satu solusi untuk pertidaksamaan dan jelaskan apa yang diwakilinya dalam situasi itu.

Membeli Buku dan Pulpen di Toko Alat Tulis

Andi ingin membeli buku dan pulpen di Toko Alat Tulis Handayana. Andi memiliki uang 20.000 yang dapat andi gunakan untuk membeli buku dan pulpen. Harga sebuah pulpen dan buku di Toko Alat Tulis Handayana berturut-turut adalah 2.000 dan 6.000, sebutkan salah satu banyak pulpen dan buku yang mungkin andi beli.

1. $2000x + 6000y \leq 20.000$ disederhanakan $2x + 6y \leq 20$
2. $x = \text{harga pulpen}$, $y = \text{harga buku}$
4. $x = 2$, $y = 2$, berarti andi membeli 2 pulpen dan dua buku

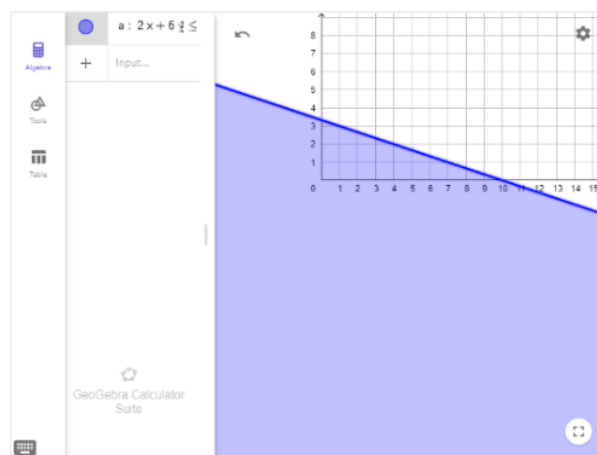


Figure 4. Application to questions that are close and realistic to students

As shown in Figure 4 at the answer column student has great respond to the problem so the teacher can give positive feedback like "Well done on your solution to the issue! Your strategy was well-planned and showed that you had a firm grasp of the idea. Your response was well-written and meticulous. I appreciate the effort you put into your work and think you did a great job of applying your knowledge to this issue. Keep up the good work and keep tackling problems of this nature to hone your abilities and knowledge". But some students do not simplify their inequality problem so the teacher can give specific feedback like "Although you have correctly solved the inequality, try to make it as simple as you can before determining the solution set to hone your problem-solving abilities". The use of GeoGebra in learning mathematics can assist teachers in monitoring students' understanding of mathematical concepts and providing appropriate feedback (Dahal et al., 2022). After students have a solid understanding of two-variable linear inequalities, the teacher can provide some linear inequalities and ask students to solve problems analytically without using GeoGebra.

The next learning design is a system of two-variable linear equations. The design that is made connects with previous learning concepts so that it can make it easier for students to process new information provided by the teacher. Comparing and contrasting, as well as connecting new concepts with one or more previously learned concepts, can make it easier for

students to process the new information obtained (Di Muro, 2006). The design created using GeoGebra is presented in Figure 5.

Menggambar dan Daerah Penyelesaian Sistem Pertidaksamaan Dua Variabel

Author: muhammad, M Algebra 1, Geometry, Algebra 2, GeoGebra Classroom Activities

Gunakan teknologi graph untuk membuat grafik wilayah solusi dari setiap sistem pertidaksamaan dan membuat grafik setiap grafik.

Selesaikan pendeskripsikan grafik sesuai kebutuhan untuk menyampaikan informasi yang bermakna.

Anda dapat menggunakan applet di bawah atau kalkulator grafik di <https://www.geogebra.org/m/ghfmg>

Halai prosedur yang diberikan atau langkah-langkah berikut ini

1. Tuliskan pertidaksamaan pertama
2. Atur warna daerah hasil pertidaksamaan pertama dengan klik setting pada titik tipa di sebelah persamaan dilanjutkan pada bagian color lalu pilih warna.
3. Ulangi langkah 1 dan 2 untuk persamaan-persamaan selanjutnya.

Gambarkan daerah pertidaksamaan dari $x \geq 0$, $y \geq 0$ dan $x + y \leq 5$.



Gambarkan daerah pertidaksamaan dari $x > 0$, $y > 0$ dan $x + y \leq 5$ dengan menuliskannya menjadi satu kesatuan dengan menggunakan tanda kurung pada setiap pertidaksamaan dilanjutkan memisahkan menggunakan "^" pada keyboard geogebra.



Figure 5. Application to a system of two-variable linear inequalities

The next design is a problem design that can stimulate students, not just use memory to solve problems. Challenge students with questions beyond the level of memory is one way to stimulate students' critical thinking. By providing more complex problems and requiring deeper thinking, students are motivated to think more creatively and develop their analytical abilities. Composing several problems that are addressed beyond simple memory skills stimulates critical thinking among students (Di Muro 2006). The following is a problem design for students using GeoGebra to make them active in learning (see Figure 6).

Tahun ini, siswa kelas 10 mengumpulkan uang pecahan 1000 dan 2000 untuk penggalangan dana sekolah.

Siswa kelas 10 pada tahun ini berusaha mengumpulkan lebih banyak dana dari dana yang diperoleh oleh kelas 10 pada tahun kemarin yang berjumlah 145.000.

menggunakan d untuk merepresentasikan banyak uang pecahan 1000 dan q untuk merepresentasikan banyak uang pecahan 2000, manakah pertidaksamaan yang paling tepat untuk merepresentasikan situasi tersebut?

Select all that apply

- A $1000d + 2000q \geq 145.000$
B $1000q + 2000d \geq 145.000$
C $1000d + 2000q > 145.000$
D $1000q + 2000d > 143.000$

CHECK MY ANSWER (3)

seorang siswa ingin membeli beberapa pasang kaos kaki untuk persiapan masuk sekolah dirinya dan adiknya.

Harga kaos kaki hitam adalah 7.500 per pasang sedangkan kaos kaki berwarna putih seharga 9.000 per pasang.

Siswa tersebut hanya diberikan uang oleh orangtuanya sebanyak 55.000 untuk membeli kaos kaki dan harus cukup.

Tulis pertidaksamaan untuk menjelaskan batasannya. Tentukan apa yang diwakili oleh setiap variabel.

As π Type your answer here...

Sebutkan salah satu solusi pertidaksamaan dan jelaskan maknanya.

As π Type your answer here...

Figure 6. Problem design for students using GeoGebra

When a problem raises a question that is important in the real-life situation it describes and thus reflects relevant aspects of the real-world situation, it has an authentic relationship with reality (Hartmann et al., 2021). So that the problem design is adjusted to the context of the real world and is relevant to students as in Figure 7 and Figure 8.

Permasalahan Harga Buku Tulis dan Pencil

Abel sedang berada di acara festival makanan. Di acara tersebut, ia membeli dua jenis makanan favoritnya, yaitu takoyaki dan sate cumi. Harga setiap makanannya pun juga terbilang murah. Total harga yang harus dibayarkan Abel untuk pembelian 6 buah takoyaki dan 3 tusuk sate cumi masih di bawah Rp72.000. Tentukan daerah penyelesaian yang menunjukkan kemungkinan harga makanan Abel!

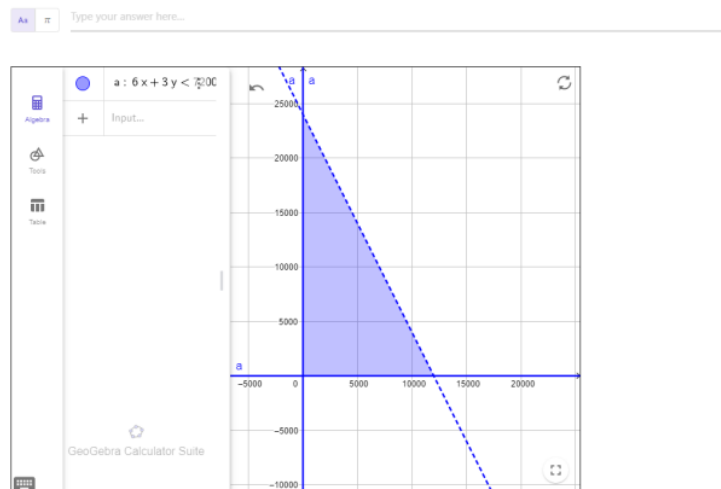


Figure 7. The design of the problem is adapted to the context in the real world

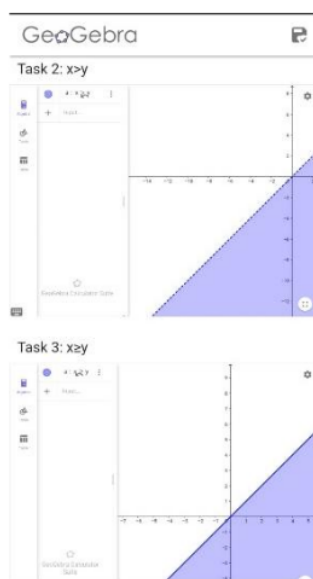


Figure 8. The results of student practice using devices

In this study the implement GeoGebra-assisted problem based learning is using applet GeoGebra in GeoGebra Classroom still need the teachers to control the students like give instructions for example in students understanding about the different representation of “>” (more than) and “≥” (more than equal to), the teacher said “can anyone explain the different about representation inequality in task 2 and task 3?” so all students in class can keep up in learning because some of students not well follow in learning process. Implement GeoGebra-assisted problem-based learning also runs without eliminating communication with each other, tracking the change process, and continuing to interact with teachers. Before the study is occurred, students had difficulties in problem formulation and mathematical modeling for

solving real-world or narrative problems. Problem formulation is the capacity to discover and specify mathematical issues based on real-world events, whereas mathematical modeling is the process of mathematically describing these problems. Due to the abstract characteristics of mathematics and the lack of link to real-world circumstances, students frequently had difficulties in framing questions. They struggled to identify and interpret the necessary mathematical components of a particular scenario into well-defined problems. This weakness hampered their capacity to successfully apply mathematical principles in actual circumstances.

Several interventions were put in place to help students with issue formulation and mathematical modeling. These interventions were created to help students link mathematical principles to real-world problems and improve their problem-solving abilities. The study discovered that following the treatments, students' ability to define problems and apply mathematical modeling increased dramatically. They indicated higher confidence when confronted with real-world or narrative difficulties, as well as greater ability in applying mathematical ideas to practical settings. The success of the learning process is supported by the results of the posttest of student learning outcomes after studying the System of Two Variable Linear Inequalities material using GeoGebra. From the learning outcomes data, it was determined that 31 out of 36 students scored more than the minimum criteria of mastery learning. Minimum criteria of mastery learning on this research is in accordance with that used in schools, namely 75. This means that as many as 86.11% of students exceed the minimum criteria of mastery learning. This is confirmed by the right-sided averaging test. From the calculation results, a significant level is $t_{count} = 6.820$ with a significant level of $\alpha = 5\%$ obtained $t_{table} = 1.6895$. Because $t_{count} = 6.820 > 1.6895 = t_{table}$ it can be concluded that the results of learning using GeoGebra on System of Two Variable Linear Inequalities material differ significantly and exceed the minimum criteria of mastery learning. Furthermore, students were given problem-solving scenarios, allowing them to use their mathematics knowledge and abilities in genuine problem-solving settings. The replies and solutions of the students to these scenarios were studied in order to assess their ability to transfer and apply mathematical principles in practical circumstances.

CONCLUSION

The use of GeoGebra in mathematics learning is able to support student exploration so that students are more involved in the learning process by paying attention to student interaction and exploration. The results of the study show that teachers need to develop student exploration processes through representations, simulations, problems, and solutions using GeoGebra that are close to student reality. The use of GeoGebra makes students active knowledge builders, learns centered on students without eliminating communicating with one another, tracks the process of change, and continues to interact with teachers, in teaching mathematical representations, simulations, problems, and solutions using GeoGebra that are close to student reality. The analysis carried out is supported by student learning outcomes, which show that the average learning outcomes are significantly different and exceed the minimum criteria of mastery learning, and as many as 86% of students score above the minimum criteria of mastery learning. The use of GeoGebra-assisted PBL significantly improved students' problem-solving skills, particularly in terms of their ability to identify problems, gather data, analyze it, and propose solutions. In addition, students felt that Geogebra was a helpful tool for quickening their learning, providing engaging and dynamic learning opportunities, and enhancing their problem-solving skills. This study's findings show that teachers may build engaging and relevant learning experiences that develop greater mathematical comprehension and help students realize the significance of mathematics in their lives by exploiting GeoGebra's capabilities. One disadvantage of this study is that the research was limited to an urban school environment while exploring the use of GeoGebra-assisted problem-based learning. The findings and conclusions drawn from this study may not be entirely relevant or generalizable to students in rural or suburban schools. The distinct qualities,

demographics, and educational environments of urban schools may influence students' experiences and outcomes differently than children in other settings.

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