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Research articles

Triangle and quadrilateral learning design through GeoGebra assisted discovery learning

Dinda Nur Salsabila[1], Dedi Muhtadi[1], Eko Yulianto[1]

Abstrak Penelitian ini bertujuan untuk merancang dan menerapkan desain pembelajaran segitiga dan segi empat menggunakan model pembelajaran penemuan yang didukung oleh GeoGebra, serta mengevaluasi hasil belajar siswa. Metode yang digunakan adalah penelitian desain (*design research*) yang terdiri dari tiga tahap: desain awal, eksperimen desain, dan analisis retrospektif. Pengumpulan data dalam penelitian ini melibatkan penggunaan teknik observasi untuk mengamati aspek-aspek relevan selama proses pembelajaran. Selain itu, proses pembelajaran direkam untuk mengumpulkan data mengenai aktivitas siswa selama fase eksperimen desain. Wawancara digunakan untuk menggali lebih dalam informasi mengenai potensi masalah yang ditemukan. Penelitian ini dilakukan di SMP Negeri 2 Cisaga, melibatkan dua kelas, yaitu kelas eksperimen pilot dan kelas eksperimen pengajaran. Hasil penelitian menunjukkan bahwa penggabungan konteks ubin dan profil gypsum dalam pengajaran konsep keliling dan luas segitiga serta segi empat secara signifikan berkontribusi dalam membantu siswa mengembangkan pemahaman dasar mengenai konsep dan rumus terkait. Selanjutnya, pemanfaatan jalur pembelajaran dalam konteks ubin dan profil gypsum melalui model pembelajaran penemuan dengan bantuan GeoGebra secara positif mempengaruhi pemahaman siswa terhadap keliling dan luas segitiga dan segi empat.

Kata kunci *Penelitian desain, Segitiga, Segiempat, Jalur pembelajaran, Pembelajaran penemuan, GeoGebra*

Abstract This research aims to design and implement a triangle and quadrilateral learning design using the discovery learning model supported by GeoGebra, as well as evaluating students' learning outcomes. The research method employed design research consisting of three stages: preliminary design, design experiment, and retrospective analysis. Data collection in this study involved the use of observation techniques to observe relevant aspects during the learning process. In addition, the learning process was recorded to gather data on student activities during the design experiment phase. Interviews were used to delve deeper into information regarding potential issues found. This research was conducted in the secondary school SMP Negeri 2 Cisaga, involving two classes, namely the pilot experiment class and the teaching experiment class. The research results indicated that incorporating tile and gypsum profile contexts into teaching the concepts of perimeter and area of triangles and quadrilaterals significantly contributes to help students developing a fundamental understanding of the related concepts and formulas. Furthermore, the utilization of learning trajectory within the context of tiles and gypsum profiles through the discovery learning model with the assistance of GeoGebra positively influences students' comprehension of the perimeter and area of triangles and quadrilaterals.

Keywords *Design research, Triangles, Quadrilaterals, Learning trajectory, Discovery learning, GeoGebra*

[1] Department of Mathematics Education, Universitas Siliwangi, Tasikmalaya, Indonesia, ekoyulianto@unsil.ac.id

Introduction

Geometry learning is a crucial component of the independent curriculum in junior high schools. At this level, 42% of the curriculum is dedicated to geometry-related content. However, despite its significance, many students still encounter challenges difficulties in mastering this topic (Baki, 2014). Sumiati and Agustini (2020); Putri et al. (2018); Hidayah and Fitriani (2021); Linda et al. (2020) have investigated the difficulties and challenges of learning mathematics in understanding triangles and quadrilaterals. According to Putri et al. (2018), the difficulty in understanding triangles and quadrilaterals is because they tend to memorize formulas without knowing where the formulas were obtained in the process of learning triangles and quadrilaterals in elementary schools.

The researchers conducted an interview with a mathematics teacher at SMP Negeri 2 Cisaga. The difficulties experienced by students in understanding triangle and quadrilateral material were mistakes in calculating the perimeter and areas, struggles with memorizing formulas, and challenges in solving questions that differed from practice exercises. Additionally, the assessment results in the triangle and quadrilateral sections have not reached the Minimum Completeness Criteria (*KKM*). As many as 25% of students have reached the *KKM*, but 75% of students did not attain the required *KKM*. Many researchers have conducted research on students' learning difficulties and obstacles in triangular and quadrilateral material such as Nursaadah and Amelia (2018); Marande and Diana (2022); Desmayanasari and Hardianti (2021); Maryati et al. (2019). They discussed how to overcome learning difficulties and obstacles students on triangle and quadrilateral material by using the method, appropriate and customized strategies, models, teaching materials and student worksheets with the student's condition. Nursaadah and Amelia (2018) suggest that it is necessary to develop methods or strategies or learning models or teaching materials that can overcome some of the difficulties in triangular and quadrilateral material.

The utilization of context in learning mathematics is very important and serves as a starting point in the learning process, fostering meaningful learning comprehension for students. Besides the use of context, to produce meaningful learning, it is necessary to choose the right learning model. Thomas and Wilma in Zein (2016) stated that in the context of the learning process in school or class, the role of the teacher is more specific in nature, namely related with the correlation between the teaching and learning process. In the context of mathematics learning, Two-way interaction between teachers and students is required to form clearly understanding related to the abstractness of mathematical concepts and theories (Yusof & Maat, 2022). The learning context used in this research was tiles and profiles plaster. The tile context and gypsum profile were selected because they could represent the Perimeter concept and area of triangles and quadrilaterals. Gypsum tiles and profiles are capable of analysis geometric shape of the visual appearance. Thus, it can improve visualization and learning analysis skills. This is in line with Rusman's opinion in Nur and Masita (2022) that the essence of contextual learning is interconnectedness between the subject matter and the experience or environment around students. This approach encourages active participation in developing their abilities as they try to relate the subject matter for their surroundings and apply it effectively.

Besides the use of context, selecting appropriate learning model is crucial for fostering meaningful learning experiences. By choosing the right learning model, students can problem situations aligned with this concept without encountering significant difficulties or obstacles. One such models that can facilitate effective learning is the discovery learning model. This

model was chosen because it is based on principles that students must search for and investigate their own concepts systematically so that they can find their own knowledge and understand the concept of learning triangles and quadrilaterals. According to Cahyaningsih and Assidik (2021), discovery learning is a learning process which focuses on finding the students' own knowledge through experiment or can observe for yourself so that learning activities become active and effective.

Related to that matter, a mathematics learning aid is required to facilitate this learning process. Dwi et al. (2022) revealed that mathematics is one of the subjects taught at all levels of education and play an important role in the development of science and technology. The role of mathematics as a basic science can be seen from the large demand for skills that must be possessed, especially in dealing with the 21st century. With today's technological sophistication, people need to take advantage of it as a complement to the learning process. The choice of GeoGebra software is based on by research conducted by Nofitri et al. (2022), which revealed that the GeoGebra application is an interactive learning media so that it can improve student motivation, interest in learning and make it easier for users to express their ideas into applications to provide opportunities in participating actively. Through this application, students are able to identify the geometric shapes either through direct construction or discoveries in the objects around them. In addition, the results of research conducted by Nofitri et al. (2022) revealed that the GeoGebra application is an interactive learning medium.

After determining its context, the researchers then compiled a Hypothetical Learning Trajectory (HLT). HLT is a student's learning journey that used as an alleged thinking strategy students in solving problems or understanding an internal concept mathematical activities based on expected goals. Researchers compiled Hypothetical Learning Trajectory (HLT) on triangles and quadrilaterals with the tiles and gypsum profiles and utilized the discovery learning model learning assisted by GeoGebra software.

In learning activities, learning resources are needed to support the learning process so that the learning objectives can be achieved properly. Apertha et al. (2018) stated that LKPD or students' worksheet is a learning tool as a complement or means of supporting the implementation of learning implementation plans because it can make students to be active in the learning process. Syamsu (2020) explains that the discovery learning model is a learning model that prioritizes reflection, thinking, experimenting, and obtaining specific conclusions, as well as training students to organize and build concepts based on their own findings so that students are actively involved directly in acquiring knowledge rather than passively reading or listening to the teacher's presentation. The stages or syntax that must be used in applying the discovery learning model are stimulation, problem statements, data collection, data processing, verification, generalization and conclusion (Puspitasari et al., 2021).

The learning process is designed and implemented using GeoGebra media. It aims to help students to understand triangle and quadrilateral material. Learning media is used to help and motivate students in learning triangular and quadrilateral material. Novilanti and Suripah (2021) stated that using GeoGebra software in the learning process can attract students' learning interest in the learning process. In learning triangular and quadrilateral material, the researchers presented a problem using the context of tiles and gypsum profiles as an initial description of learning contained in a Student Worksheet (*LKPD*). Therefore, the researchers intended to design triangular and rectangular materials learning using the context of tiles and gypsum profiles through GeoGebra-assisted discovery learning model. It is expected that this can overcome difficulties and facilitate students in understanding triangles and quadrilaterals. This

research aims to design and implement a design learning on Triangle and Quadrilateral material through discovery learning model with the help of GeoGebra then examined the achievement of students' learning outcomes.

Methods

This research employed the research design research methods. The choice of the research design method aligns with the problem statement and objectives of this study, which aim to develop a learning trajectory on triangle and quadrilateral material through GeoGebra assisted discovery learning. Research design is a methodology used to design and develop educational interventions. In the Indonesian context, research design involves systematically designing educational interventions, encompassing design, development, and evaluation activities aimed at enhancing the quality of educational activities or programs (Putrawangsa, 2019). Design research can be said to be appropriate research methods to develop solutions (settlements) based on research for a complex problem in educational practice for develop or validate a theory about the learning process and learning environment (Prahmana, 2017). There are three stages involved in design research: preliminary design, design experiment, respective analysis.

This research was carried out at SMP Negeri 2 Cisaga, Sukahurip Village, Cisaga, Ciamis Regency. The subjects in this research involved class VII students at SMP Negeri 2 Cisaga 2022/2023 consisting of two different classes. The subject was VII C as the experimental pilot class, and research subject was VII A class as experimental teaching class based on lesson plans on the concept of perimeter and area of triangles and quadrilaterals that have been designed. In this study, there were two classes used for thir research, namely the first cycle at the pilot experiment stage and the second cycle at the teaching experiment stage by implementing the triangle and quadrilateral learning design through the help of discovery learning GeoGebra, which had been designed by the researcher based on the HLT plan. Class VII C was used as a pilot experiment with 23 students, while class VII A was used as a teaching experiment with 23 students. In this research, data collection was carried out by observation, interviews, video recording, and testing student learning outcomes. Figure 1 displays the details of design research conducted in this study.

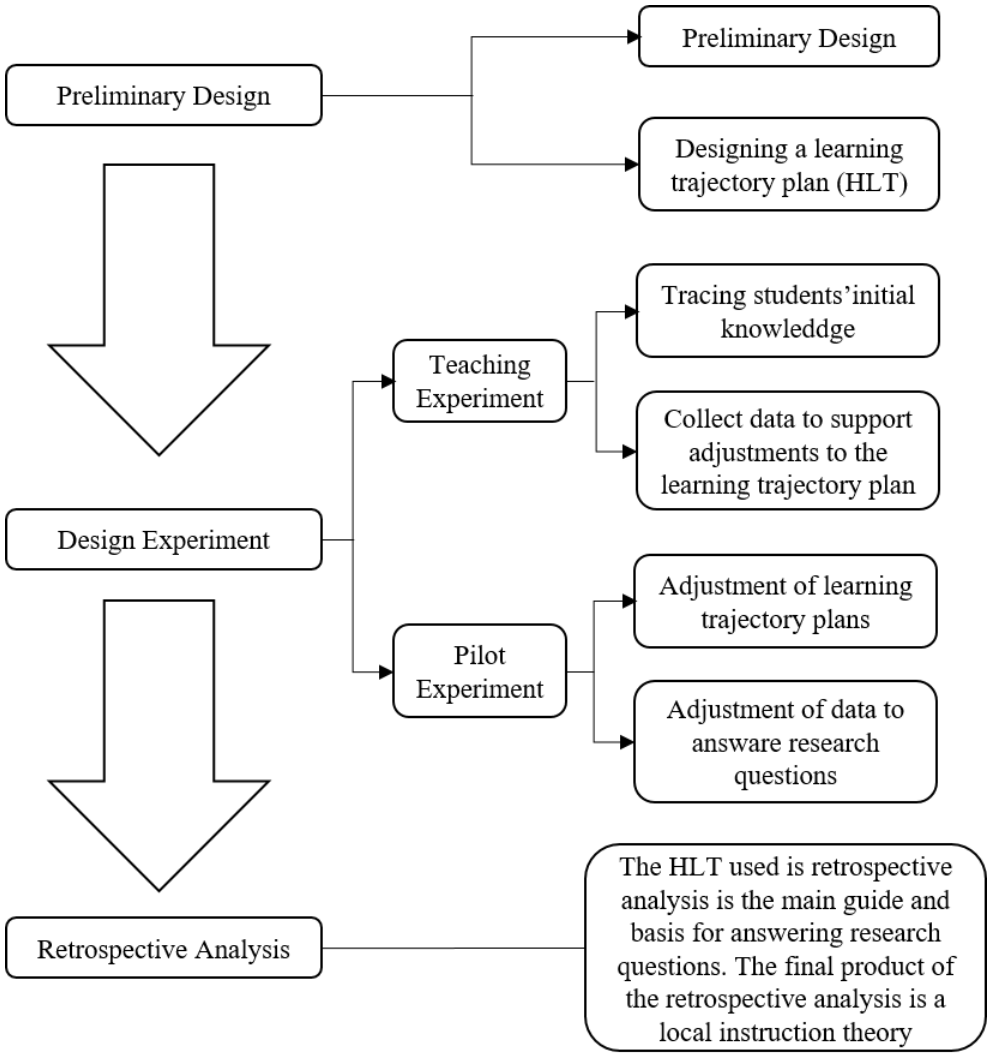


Figure 1. Research procedure

Findings and Discussion

The results of this study resulted in the learning trajectories of students on triangle and quadrilateral material through the discovery learning model assisted by GeoGebra at class VII SMP Negeri 2 Cisaga. The learning trials were carried out in two cycles, namely pilot experiments and teaching experiments. HLT improvements were carried out after the pilot experiment stage, the results of these improvements were applied to the teaching experiment stage. Table 1 describes the conditions during the pilot and teaching experiments.

Table 1. Comparison of research design experiments results

Aspects	Pilot experiment	Teaching experiment
Learning Activity Planning	Early learning activities are designed based on the assumption of how students will understand and learn the concept of triangles and quadrilaterals through GeoGebra-assisted discovery learning. These activities focus on exploring concepts using GeoGebra and manipulating real objects (tiles and gypsum profiles).	After analyzing the data from the pilot class, improvements were made by clarifying the instructions and increasing the scaffolding given to students. For example, if in the pilot class students showed confusion when using GeoGebra, in the teaching experiment, clearer tutorials and step-by-step guides were added to help students understand how to use the tool more effectively.
Use of Assistive Devices	The use of GeoGebra and real objects such as tiles and gypsum profiles were introduced simultaneously. However, some students seemed to have difficulty in connecting the concepts explored in GeoGebra with real objects.	Improvements were made by strengthening the link between GeoGebra activities and real-world object manipulation. GeoGebra activities were more seamlessly integrated with hands-on experiences using tiles and gypsum profiles, so that students could more easily make connections between digital visualizations and physical forms of the same concept.
Learning Structure	• The learning structure is more open, with the expectation that students will discover concepts independently through exploration. However, observations showed that some students felt confused without sufficient guidance. • Students were able to answer the LKPD. However, there were several misconceptions at the first meeting in learning activities 1 and 2. Students did not know the meaning of the hypothesis words because they had not learned the definition of the hypothesis word. It also occurred at the second meeting in the data collection and verification section.	• The learning structure is improved by providing a clearer framework for students, including checkpoints where teachers facilitate discussions to ensure that all students are on track. Learning remains discovery-oriented, but with more guidance from the teacher. • After revising LKPD, there was an increase in answering questions in LKPD according to the expectations of the researchers.
Difficulty level of Material	The material presented in HLT may be too challenging for some students, especially those who have difficulty visualizing geometry.	The level of difficulty of the material is adjusted based on feedback from the pilot class. A gradual approach is introduced, moving from simpler concepts to more complex ones, with an emphasis on basic understanding before moving on to more complex topics.

Student learning outcomes test	• Assessment was conducted through observation and simple tests to measure students' understanding of the concepts taught. However, it was found that some questions did not fully reflect the activities carried out in class. • Students had been able to answer the LKPD correctly, but there were six students who had not answered the questions correctly.	• Improvements were made by designing better assessments that were aligned with learning activities and more accurately measured students' conceptual understanding. Tests and assignments were improved to better reflect the practical application of the concepts of circumference and area of triangles and quadrilaterals, both digitally through GeoGebra and physically with real objects. • There was an increase in answering the learning outcomes test questions out of 23 students. There were 22 students who answered the questions correctly and 1 student was not able to answer the questions correctly.
Class Interaction and Discussion	Interaction between students and teachers tends to be less intensive, with a focus on independent exploration. As a result, some students feel less directed.	Interaction is enhanced with more discussion and reflection sessions, where students are encouraged to share their findings and discuss challenges they face. Teachers play a more active role in facilitating discussions and helping students overcome difficulties they face.
Feedback and Revision	Student feedback and classroom observations revealed several weaknesses in HLT, including the need for clearer instructions and better scaffolding.	Based on this feedback, the HLT was significantly revised. The material was clarified, activities were simplified, and the connection between theory and practice was strengthened. Students were also given more opportunities to reflect on their learning through group discussions and presentations.

The context of tiles and gypsum profiles plays a very important role as a starting point in learning the perimeter, area of triangles and quadrilaterals from real to abstract shapes with the help of software GeoGebra. Based on research that has been carried out, at the initial design stage, the students have difficulty understanding the concept of perimeter and area of a triangle and quadrilaterals, especially in determining the area and perimeter formulas for triangular shapes and quadrilateral. This was because students were introduced directly regarding the formulas for the perimeter and area of triangles and quadrilaterals without understanding the formula was obtained and not connected to their daily lives. In learning process, there is a need

for connection with daily life so that educators can guide students to discovery of the concept of triangle and quadrilateral material.

In the context of mathematics learning, two-way interaction between the teacher and students are needed to form a clear understanding of abstract concepts mathematics and theory (Yusof & Maat, 2022). Based on the activities that have been carried out, it can be seen that the use of the Gypsum tiles and profiles context through GeoGebra's discovery learning model can help educators in teaching the concept of perimeter and area of triangles and quadrilaterals so that students can better understand its concepts. The teacher's task aimed to provide context and engage students in a variety of activities that allow students to connect lesson material with things in their real life (Yayuk et al., 2018).

The following is a summary of the researcher's interview transcript with four subjects (R1, R2, R3, and R4) to determine students' responses after the learning design was implemented.

Researcher : I want to talk a little about the geometry lesson that we are studying, especially about triangles and quadrilaterals. Before that, I want to ask, do you know what tiles are?

R1 : Yes, ma'am. Tiles are the ones that are usually used for floors, right?

Researcher : That's right. What about gypsum profiles? Are you familiar with them?

R2 : I know, ma'am. Gypsum profiles are usually used for decoration on the ceiling or walls of a house, they come in various shapes.

Researcher : That's right. Do you find it easier to understand the concept of circumference and area when using real objects like this compared to just through pictures or formulas on the board?

R1 : Yes, ma'am. When I only see formulas, sometimes I'm confused about where to start. But if there are real objects, I can immediately practice measuring and calculating, so I understand better.

R3 : Yes, ma'am. If we measure the sides of a square tile, we can immediately calculate the circumference and area more easily because we can see and touch the object directly.

R4 : I think so too, ma'am. With a triangular gypsum profile, we can learn to calculate its area and circumference by measuring its sides. So, it is more real and easier to understand than just looking at pictures in books.

Researcher : Very good. Can you tell us about your experience using tiles or gypsum profiles in learning?

R2 : Last week, the teacher brought some tiles to class. We were asked to measure the sides and calculate the circumference and area. That way, I understand that the area is actually the amount of area covered by the tile, and the circumference is the total length of all its sides. So the concept is clearer in my head.

Researcher : Very interesting. Is there a change in your understanding after doing the activity?

R3 : Yes, ma'am. Previously, I often made mistakes in calculating the area because I mistakenly multiplied the length and width. But after direct practice, I remember the steps better and know where the numbers come from.

Researcher : How about using GeoGebra in this learning? Do you think the combination of real objects and applications like GeoGebra helps in understanding the material?

R4 : In my opinion, the combination of both is very helpful, ma'am. With real objects, we can understand the basic concept, then with GeoGebra we can see various

variations of shapes and try to change their sizes quickly. So, the understanding is broader and deeper.

R1 : I agree, ma'am. GeoGebra helps us see how changes in size affect area and circumference directly, while real objects help us understand and feel the shape physically.

Figure 2 is the context used during the learning process and Figure 3 is the result of students' worksheet presented in the conclusion section. Rusman in Nur and Masita (2022) stated that the essence of contextual learning is the correlation between subject matter with experience or the environment around students, so that students actively participate to develop their abilities as students try to learn the subject matter and get close to the surrounding environment and able to implement it. Based on research that has been conducted, students have able to find the definitions of perimeter, area, how to determine perimeter and area based on the problem provided. This is because they are able to develop their abilities about triangle material and quadrilaterals and their moments with everyday life. Isharyadi (2018) explained that the contextual problems presented in class encourage students to make connections between the knowledge they have and its implementation in their lives. Applying real-world contexts in studying mathematics subjects, especially triangle and quadrilateral material can make it easier for educators to explain concepts and material, show to students directly, and as a means to convey learning easily.

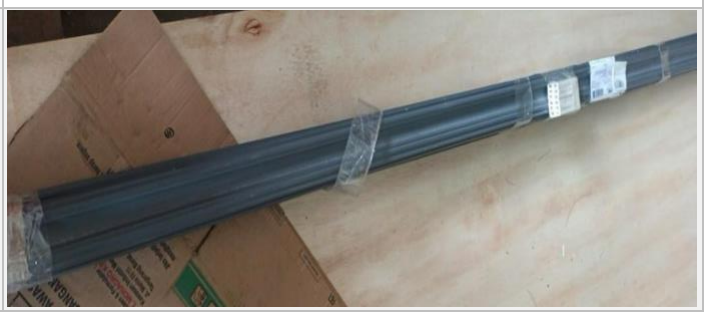
Tiles	Gypsum
	

Figure 2. Tiles and Gypsum profiles as learning context

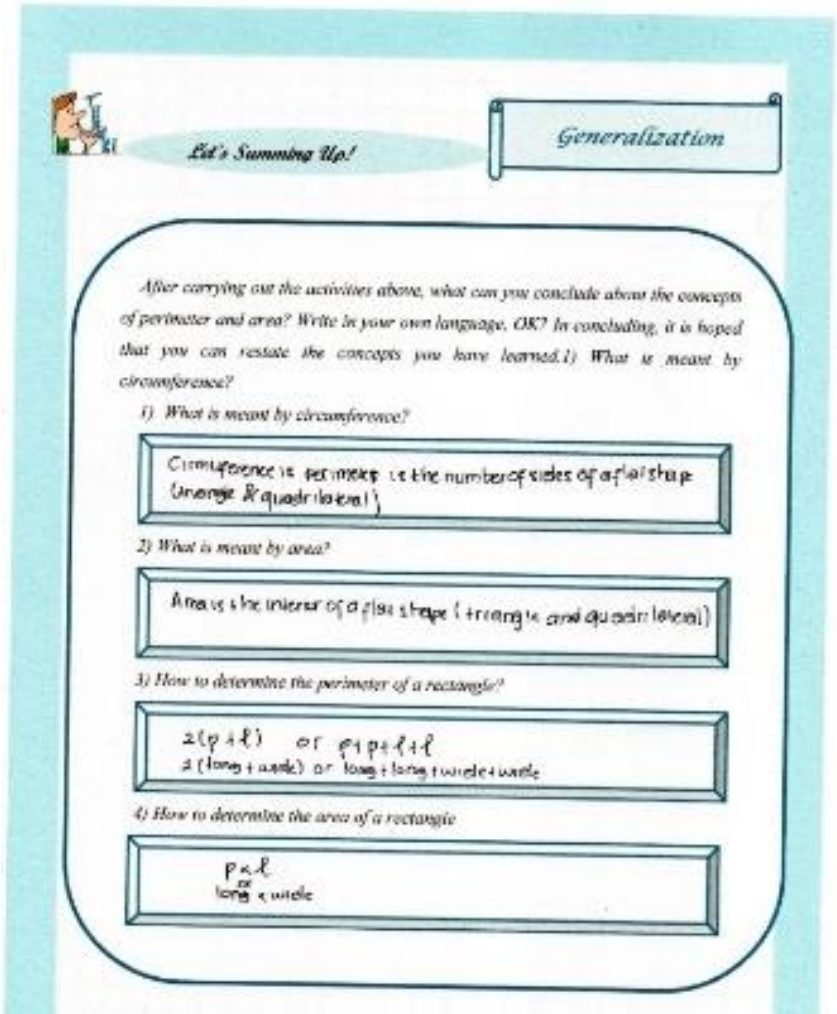


Figure 3. Students' answer to learning activity 1 in the first meeting

Meanwhile, based on the worksheet on the learning outcomes tests carried out by students, it can be said that there is an increase in the results of the learning outcomes test questions carried out at the pilot experiment stage, especially in questions number 1, 2, and 3. Students answered the learning outcomes test in accordance with the expectations of the researchers and there was a significant increase in the learning outcomes tests conducted at this teaching experiment stage. Learning outcomes test questions were arranged based on learning outcomes and objectives using Bloom's taxonomy approach, namely C3 (applying) and C4 (analyzing) with the aim of collecting information about the strategies used in solving problem related to triangles and quadrilaterals.

In the retrospective stage of this study, it was found that some students in the pilot experiment class had difficulty in following the learning trajectory that had been planned in the HLT. One of the main difficulties experienced by students was in understanding the term "hypothesis," which is often considered an abstract and difficult concept to understand. In addition, in learning the concept of base and height, students tended to use terms that were more familiar to them, namely length and width, which came from their habits in elementary education. This shows that the initial assumptions in the HLT regarding students' understanding

of certain terms were not entirely accurate. Students' responses to learning activities were also not entirely in accordance with what was expected in the HLT that had been designed. In response to these findings, the researcher revised several aspects of the HLT. This revision included improvements to the instructions and questions in the Student Worksheet (LKPD), with the aim of reducing student confusion about new terms and more complex geometric concepts. In addition, the researcher also revised the anticipated student response estimates, and added educator strategies to handle responses that were not in accordance with expectations. The re-implementation of the revised HLT in the teaching experiment class showed significant improvements, where the difficulties that emerged in the pilot experiment stage did not recur. This shows that the revised HLT is more effective in helping students understand the geometry concepts taught.

In the teaching experiment class, with the revised HLT, students showed better abilities in following the planned learning trajectory. They were able to complete activity problems, such as calculating the number of ceramic tiles and gypsum profiles needed in real contexts, to abstracting the concepts of the circumference and area of triangles and quadrilaterals. A more structured learning process, from the stimulus stage to generalization, helped students connect their learning experiences with more complex abstract concepts. This shows that improvements in the HLT, which involved revised instructions, predicted student responses, and a more contextual approach, successfully addressed the challenges faced by students in the pilot experiment stage.

Overall, the results of the implementation of the revised HLT showed that students were not only able to understand the geometry concepts taught, but were also able to apply them in real contexts. The use of concrete objects such as tiles and gypsum profiles, integrated with GeoGebra-assisted learning, helped students to understand and internalize the concepts of the circumference and area of triangles and quadrilaterals more deeply. These results demonstrate the success of the discovery learning approach supported by physical and digital aids in improving students' understanding, while also emphasizing the importance of revising the HLT based on initial findings from the pilot experiment class. Table 2 below shows the percentage of students' achievement test results.

Table 2. Percentage of students' learning outcomes

Class	Problem number	Mark	Percentage	Number of students	Number of students answered correctly
Pilot experiment	1	≥ 76	100 %	23 students	23 students
	2	≥ 76	96 %	23 students	22 students
	3	≥ 76	78 %	23 students	18 students
Teaching experiment	1	≥ 76	100 %	23 students	23 students
	2	≥ 76	100 %	23 students	23 students
	3	≥ 76	96 %	23 students	22 students

Table 2 shows a significant increase in student learning outcomes from the pilot experiment and teaching experiment classes after the revision of the Hypothetical Learning Trajectory (HLT). In the pilot experiment class, although all students were able to achieve a score of ≥ 76 on the first question, there was a decrease in performance on the second question, where only 96% of students answered correctly, and even more significantly on the third question, where only 78% of students were able to answer correctly. This decrease indicates difficulty in understanding more complex or new concepts. After the revision of the HLT, which was applied

to the teaching experiment class, the results showed a significant increase in student understanding. On the second question, all students (100%) managed to answer correctly, in contrast to the pilot class where there were some students who still had difficulty. The most prominent increase was seen in the third question, where the student success rate increased from 78% in the pilot class to 96% in the teaching experiment class. This shows that the revisions made, including improvements to instructions, teaching methods, and the integration of the use of GeoGebra and concrete objects such as tiles and gypsum profiles, succeeded in overcoming the difficulties previously experienced by students. Overall, these results confirm that a more structured and contextual approach to learning helps students better understand the concepts of perimeter and area of triangles and quadrilaterals. This is in line with research conducted by Nursaadah and Amelia (2018); Marande and Diana (2022); Desmayanasari and Hardianti (2021); Maryati et al. (2019) about how to overcome learning difficulties and obstacles students on triangle and quadrilateral material by using methods, strategies, models, open materials, and student worksheets that are appropriate and adapted with the condition of the students.

Conclusion

The use of context tiles and gypsum profiles in designing learning the perimeter and area of triangles and quadrilaterals has a very important role as an initial starting point for learning process, which can increase students' motivation and understanding in learning perimeter and area of triangles and rectangles. Gypsum tiles and profiles are able to encourage students to understand and solve problems in their daily life activities related to the perimeter and area of triangles and quadrilaterals so that they can build students' language regarding those concepts. The learning trajectory was started from solving problems presented using the context of tile and gypsum profiles.

The limitation of the research is the learning design using the discovery learning model with the help of GeoGebra software. This is a fairly new medium for students, so there are still many unfamiliar. The use of large amount of computer makes the researchers need to pay more attention to students during the learning process to avoid risk of students using them for other purposes outside the learning process. The time provided by the school is relatively large but there were often delays in student activities, making the implementation of learning design for triangular and rectangular materials through the discovery learning model with the help of GeoGebra software could be carried out as efficiently as possible. The researchers hope that there will be further research that focuses on learning design research using different learning contexts, so that varied learning can be carried out. It can increase students' interest in learning and understanding of concepts and interest in learning that increase better understanding, particularly the materials taught through other contexts related to students' daily lives.

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