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GEOGEBRA-ASSISTED INDUCTIVE REASONING IN PROJECT-BASED LEARNING THROUGH A WEB-BASED SYSTEM

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Abstract

Learning that involves the use of GeoGebra software in the establishment of mathematical concepts has been focused on simulation and the effectiveness of the learning outcomes obtained, but some explore the use of the software in learning how to produce products in the form of GeoGebra applications as assistance in the establishment of inductive reasoning. Through project-based learning (PjBL) on a web-based learning system, independence in the discovery and formation stages of an inductive reasoning process can be trained. The purpose of this research was to develop GeoGebra applications to assist students in solving problems and finding concepts in geometry in the plane and space through inductive reasoning. The research was conducted on 34 students who took geometry in the plane and space course. The research method used was the design research method of the validation study type, while data collection was performed using observation during the learning process and documentation. Inductive reasoning in this research was carried out through the exploration of concepts via the GeoGebra applications developed, following the stages of observing several examples of the concepts, searching for and testing patterns from the examples of the concepts, and generalizing these findings into a concept. Through the use of the GeoGebra applications produced, students could develop independence and creativity, where they could think independently in their search for knowledge. This research concludes that inductive reasoning can be performed using the GeoGebra applications produced, whereby the concepts of the area of a shape, circles, and a common internal tangent to two circles can be explored.

Keywords: GeoGebra, Inductive reasoning, Project-based learning, Web.

1. Introduction

One of the skill components that can support the development of cognitive abilities is inductive reasoning [1, 2]. It can help with finding basic regularities in generalizing concepts [3], train problem-solving skills [4, 5], assist the critical thinking process [6], and influence the development of thinking and cognitive skills [7-10]. This shows that inductive reasoning plays a pivotal role in the learning process [1, 11]. Students get opportunities to analyse new situations in various aspects, make logical assumptions, explain thoughts and findings, draw and defend conclusions [7], and detect regularities, rules, and generalizations as well as disorders [3, 9].

The importance of inductive reasoning in students' cognitive skills development has been stated by previous researchers. It has been found that lecturers experienced considerable difficulties in performing assessments [7] and that students encountered hardships in solving complex problems that required generalizations from certain cases [4, 12]. The development of cognitive skills itself is necessary for new knowledge creation [13], which requires tasks involving inductive reasoning [14]. Research results indicated the importance of lecturers' role in designing controllable learning and assessing the learning process along with the student activities conducted, especially in distance learning. Technology use can offer a solution to this series of challenges [15].

The use of the Internet and software in learning is needed [16-21]. This includes the use of the web in learning. The web, containing data on all learning activities as well as visual and interactive instruments, can be used for distance learning and be designed for evaluations and practices [22-24]. The web can provide a plethora of learning experiences regardless of time and space [23, 25]. Still, there is a need for learning to be student-centred to develop students' thinking and reasoning skills and to encourage creativity and innovations in learning. The use of technology can also provide a stronger learning motivation in the 21st century [15, 26]. It has become a focus in current learning processes, and it can involve students in more meaningful learning [27-30].

To promote these abilities, a learning model with the use of technology in the learning implementation is needed. Existing scientific literature suggests that the use of the web must be accompanied by an appropriate learning approach [25]. One of the available approaches is the Project-Based Learning model. This model can be implemented to improve mathematical abilities, shape scientific behavior, and improve students' responsibility and independence in learning [31, 32]. project-based learning (PjBL) is a learning model in which students are directly involved in project planning and repeated explorations to find concepts [33] for them to gain meaningful experiences and skills as a prerequisite to solving actual problems in life [34]. For students to acquire mathematical skills and abilities, the steps they must go through in PjBL include constructing problems, conducting investigations, planning, developing ideas, presenting ideas, providing feedback, and revising and re-presenting products [35, 36].

PjBL, which has been implemented face-to-face, is expandable to also use software technology for learning in the virtual space [37]. Incorporating technology in learning under the PjBL model, as in using computers and software, will give better results [38-41]. Research on the application of the PjBL model in conjunction with the technology used to establish mathematical concepts has indicated good results in a variety of ways. This research includes the work on the use of technology as a medium in a teaching process under the PjBL model [42] to produce products in the form of learning tools. Some researchers used the YouTube platform as a learning resource for project completion [43], and, recently, other researchers developed virtual learning activities by combining the PjBL model and technology, presenting the product online to students from various countries. However, in the current state of online learning, the PjBL model has yet to be used to examine learning processes that are implemented completely online over the web. More specifically, there has been no learning project that makes use of technology, in this case, GeoGebra, to produce applications for establishing mathematical concepts through inductive reasoning.

Some pieces of research on the use of GeoGebra have been successfully carried out, including the research on the development of interactive e-books using GeoGebra [44], the effectiveness of using GeoGebra in learning [45], the use of GeoGebra to check the correctness of the process of completing a given task [46], and the use of GeoGebra to visualize curves and graphs [47]. From the literature review, it was figured out that the existing research on the use of GeoGebra so far studied effectiveness in terms of learning outcomes and implementation through simulations during the teaching process, but no one study has reported learning experiences gained from exploring concepts using GeoGebra software and production of GeoGebra applications to form mathematical concepts. This has rendered us to take interest in researching how a GeoGebra application project will help with students' inductive reasoning development in understanding the concepts of the area of a shape, circles, and a common internal tangent to two circles. Therefore, this study aims to produce Geogebra applications using a web-based PjBL model to help find concepts of geometry in the plane and space course through inductive reasoning.

2. Method

This research used the design research method, which is of different characteristics from other kinds of research [48]. There were three steps involved in implementing the design research method: preparing for the experiments, designing the experiments, and conducting a retrospective analysis [49-52]. This research was conducted in the geometry in the plane and space course, involving 34 students in the Mathematics Education Study Program, Faculty of Teacher Training and Education, University of Bengkulu, to numerical data, as outlined in Appendix A.

2.1. Preparing for the experiments

At this stage, the main goal was to formulate a local learning theory through elaboration and making improvements during the research [53-55]. In preparing for the experiments in this research, the first thing to do was review the literature [32], regarding the PjBL model, web-based learning, use of GeoGebra in learning, and inductive reasoning. Then, we and the lecturer who was influential in the class collaborated to design an inductive reasoning promotion project to improve the understanding of the concepts of the area of a shape, circles, and a common internal tangent to two circles. The preparation carried out at this step encompassed analyzing the learning objectives, making web-based student worksheets, and devising lecture program units, grids, observation sheets, and possible student answers. We and the lecturers who supported the course also designed some online learning processes with a priority for collaboration between the students and the lecturer in the learning implementation. The project to be carried out by students here was the creation of GeoGebra applications as an assistance for students to acquire inductive thinking skills to understand the concepts of the area of a shape, circles, and a common internal tangent to two circles.

2.2. Designing the experiments

Designing the experiments in this research was a step consisting of two parts: pilot experiment and teaching experiment [31, 32]. In the first part, an experiment was carried out in small groups of 10 students from different geometry in the plane and space classes. The students selected to be subjects were students of high, medium, and low abilities. We served as model lecturers. In the pilot experiment, the learning design that had been made was tested for its validity. The results were used to make some revisions to the products before they were to be used for the teaching experiment. The revisions made concerned the problems that remained unsolved during learning, the strategies to overcome the problems found in the pilot experiment, and uncontrollable activities in online learning. These revisions were made to make a better learning process and obtain optimum results [54]. The second part was a teaching experiment that was carried out to evaluate the learning process based on the learning objectives [32], particularly to evaluate the GeoGebra application-making project to establish students' inductive reasoning abilities in understanding the concepts of the area of a shape, circles, and a common internal tangent of two circles, which involved the activities of exploration and discovery. The teaching experiment involved 34 students of different ability levels.

2.3. Retrospective analysis

The last stage was a retrospective analysis. Data were collected by interviewing the lecturer in charge of the class, observing interactions and communications that took place during the online learning process over the virtual medium Zoom, and performing documentation of students' web-based worksheets. The data were analyzed descriptively by examining the results of the observation and documentation. The use of web-based student worksheets was focused on projects making GeoGebra applications that used online GeoGebra software in establishing an understanding of the concept of the area of a shape, circles, and a common internal tangent to two circles by involving inductive reasoning.

3. Results and Discussion

Instruction was carried out in the geometry in the plane and space course with a focus on the materials of the areas of triangles and quadrilaterals, circles, and a common external tangent to two circles. The learning process was designed under the web-based PjBL model. A web was designed in the form of student worksheets that involved inductive reasoning. GeoGebra software was explored to design GeoGebra applications as a project.

In the pilot experiment, six students with high, medium, and low abilities were involved. The selection of the students was based on grade point averages and scores gained in the basic mathematics course as a prerequisite course for taking the geometry in the plane and space course. The activity conducted was at a low level because the students' abilities to understand corresponding angles, points, and sides were low. As a result, it was considered necessary that we and lecturers strengthen the students' basic knowledge first before conducting a teaching experiment. This article would focus on the teaching experiment that involved 34 students. Activities were focused on the collaboration between students in designing learning trajectories through the making of GeoGebra applications and data analysis involving inductive reasoning for the students to gain an understanding of the concepts of the areas of rectangles and triangles, circles, and a common external tangent to two circles.

The implementation of the teaching experiment involved asynchronous learning and synchronous learning. Asynchronous learning was implemented using a web design in the form of student worksheets following PjBL learning steps, whereas synchronous learning was carried out in discussions via the Zoom application to justify the concepts that had been investigated and generated. Learning under the PjBL model promotes cooperation and independence in learning, and it involves discussions [30, 55]. It was hoped that through collaborations, students would learn from each other and complete their assignments responsibly [32]. Collaborations were established by putting together members of higher abilities and those of lower abilities [31]. The learning process under the PjBL model went through several stages: project determination, completion of the project design, preparation of the project implementation schedule, completion with facilitation and monitoring, a compilation of reports, and presentation of project results [56, 57]. Speeds are analyzed in this paper.

3.1. Project determination

The first stage in PjBL was project determination. In this stage, the students determined special cases to be used in exploring GeoGebra software to form GeoGebra applications. The aim was to direct and detect regularities to enable the students to identify the same basic idea from each specified special case [20], shown in Table 1.

Table 1. Problems in project determination.

Materials	Selected Cases
The Area of a Triangle	Determining three different kinds of triangles
The Area of a Parallelogram	Determining three kinds of parallelograms of various sizes and forms
The Area of a Trapezoid	Determining three kinds of trapezoids of various sizes and forms
The Area of a Kite	Determining three kinds of Kites of different sizes
The Definition of a Circle	Determining two points under the condition that one point was the center point and the other point was a movable point at a fixed distance from the center point
The length of a common external tangent of two circles	Determining two circles of different forms and determining the length of the common external tangent to two circles

Using the problems set out in Table 1, the students explored GeoGebra software to develop GeoGebra applications to promote inductive reasoning abilities to discover the concepts about the materials. The students also began to design and decide on the sizes and forms of the shapes that would be used in GeoGebra software to solve the questions posed on the web for concept discovery.

3.2. Project design completion

The stage of the completion of the project design was carried out after the students determined the forms and sizes of the shapes that would be used in GeoGebra software; these students would explain how to make a GeoGebra application according to the concepts that were to be discovered. On the web page, the students went through the steps to make the applications they were to produce and determined the concept of the area of a triangle (Fig. 1).

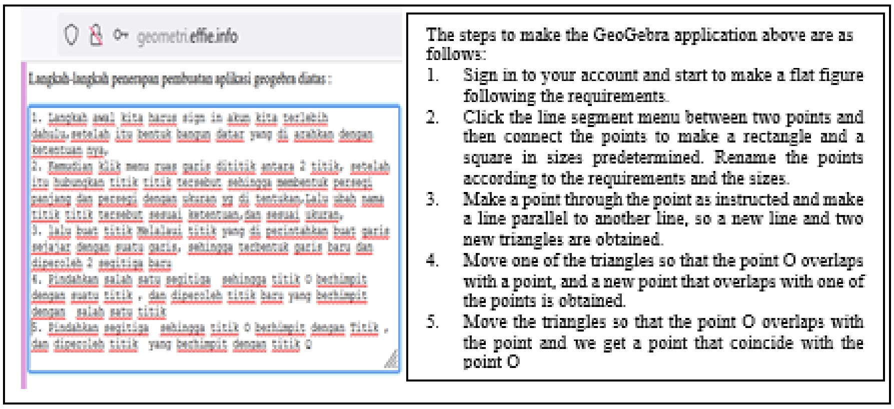

Fig. 1. GeoGebra application design for the concept of the area of a triangle.

As shown in Fig. 1, the students had to explain how to make image movements and input numbers according to the lengths of the sides of the triangles desired. The triangles formed were of three types, namely the equilateral triangle, the isosceles triangle, and the scalene triangle. The lengths of the sides of the triangles could be seen in the GeoGebra software input. The GeoGebra application design presented in Fig. 1 was still incomplete. In addition, the students also explained how to make applications to determine the area of a parallelogram and the area of a trapezoid.

The students made three types of parallelograms of different sizes, and they designed three types of trapezoids of different forms and sizes. From the steps to make the applications as contained on the web, an explanation as to how to create movement buttons for parallelograms and trapezoids was provided, hence facilitating planning. Then, steps to show the definition of a circle and to calculate the length of a common internal tangent to two circles were also generated. The resultant application design was improved. The students explained in more detail the steps for making an application to show the definition of a circle. Meanwhile, it has also been generated that the desired number input field was provided to determine the length of the radius to two circles to calculate the length of the common internal tangent to two circles.

3.3. Preparing for the project implementation schedule

After the project design was completed, the students proceeded to prepare a project implementation schedule. This project implementation schedule preparation was intended to stimulate a sense of responsibility and independence in the students. Thus, the projects that had been designed could be completed correctly and on time. The project was carried out for four weeks, in the second and fourth of which the students performed presentations, and calculate the length of the common internal tangent to two circles.

3.4. Completion of lecturer facilitation and monitoring

The next step was the facilitation and monitoring by the lecturer for the students to complete their GeoGebra application-making project. The GeoGebra application produced directed the students to think through inductive reasoning. Existing GeoGebra application output data were connected by solving the questions on the web to discover concepts. In finding the concept of the area of a triangle, the resulting application is shown in Fig. 4.

Finding concepts would involve an inductive reasoning process to generalize concepts through certain cases. The success of generalizing concepts that have been generated inductively can be achieved through three cognitive processes, namely observing regularities, forming patterns, and formulating generalizations. In finding the concept of the area of a triangle, high-ability students observed regularities in three types of triangles, namely isosceles triangles, equilateral triangles, and scalene triangles (see Fig. 2). Figure 2 also shows that the students had been able to provide a play button for observing regularities and forming patterns in the process of concept discovery on the GeoGebra application, where the three types of triangles would eventually form a rectangular area.

Medium-ability students were able to design a GeoGebra application to construct the concept of the area of a parallelogram (see Fig. 3). They used three forms of parallelograms of different sizes and completed the play button to produce a new shape, namely a rectangle. By contrast, low-ability students still made errors and met some difficulties in producing a GeoGebra application (see Fig. 4). As a result, the new shapes generated were not clear and correctly formed. Figure 4 shows that the students were to establish regularity in determining the area of a trapezoid by using the area of a parallelogram. However, in the case of the trapezoid ABCD, the final shape to be produced was not a parallelogram. This illustrates that, in solving mathematical problems, the students still displayed low abilities to form patterns and connect between concepts, while, according to literature [58], finding patterns and connecting them to a problem will stimulate thinking skills.

To promote inductive reasoning, students need to be trained to organize and produce their knowledge through interrogation and group discussion [59]. For this reason, the lecturer helped and directed students who had difficulties solving problems. In addition, the lecturer also instructed students who had been able to solve their problems to assist their group mates by discussing over the web page.

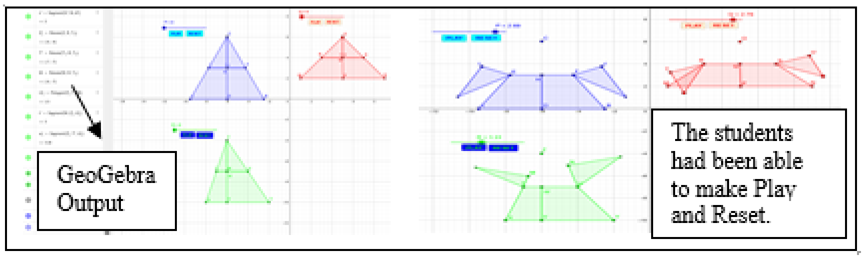

Fig. 2. GeoGebra application for the concept of the area of a triangle.

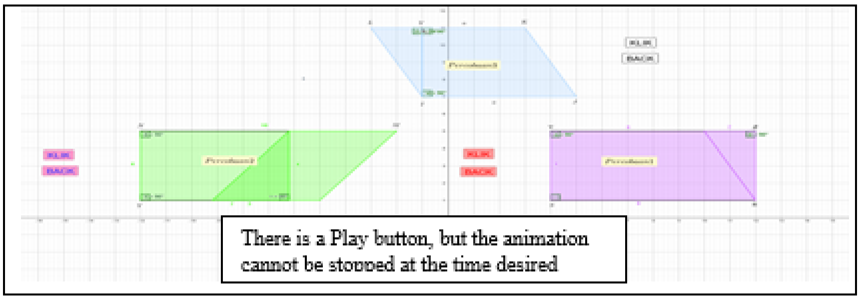

Fig. 3. GeoGebra application for the concept of the area of a parallelogram.

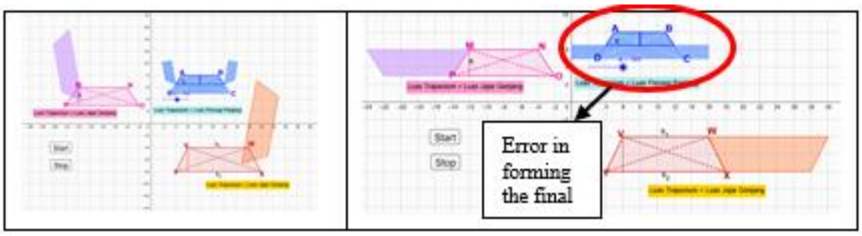

Fig. 4. GeoGebra application for the concept of the area of a trapezoid.

3.5. Preparation of reports and presentations

After the students received directions and input from the lecturer and carried out discussions with their group mates, they started to prepare reports and presentations. In this stage, they used the GeoGebra applications generated from the previous step and the GeoGebra output obtained for generalization in finding concepts. They completed the data and identified the regular patterns that were formed, made a prediction, and collected proofs in developing and identifying assumptions based on empirical data [54, 57]. In addition, under the PjBL model, they were also trained to explain their ideas and communicate their reasons for drawing their conclusions about the concepts they had found [31, 57]. The following are the results of the student activity of connecting the existing data in the GeoGebra input by completing the question table on the web as a process of finding the concepts of the area of a triangle and the area of a parallelogram.

The regularity identified in determining the areas of the triangles contained in Figs. 2 and 5 showed that the students used three types of triangles, namely the equilateral triangle, the isosceles triangle, and the scalene triangle, and they did observe the regularity of the patterns formed. The students could explain the conclusion drawn that across different types of triangles, there was a regularity: the length of the rectangle was equal to the side of the base of the triangles, and the width of the rectangle formed was equal to the height of the triangles. In this manner did the students discover the concept of the area of a triangle. This was also the case with the student’s discovery of the concept of the area of a parallelogram (Fig. 6), where they used three kinds of parallelograms of different sizes. It was found that the students were able to show that the area of a parallelogram would be the same as the area of a rectangle. In other words, the area of the parallelogram = base x height. This shows that inductive reasoning enabled the students to acquire new knowledge and helped them generalize mathematics using special cases [54, 58]. The experience of producing GeoGebra applications would be a meaningful learning experience for the students as prospective mathematics teachers in finding concepts, and this experience was expected to apply to teaching activities in the field in the future.

All the students made improvements after discussion and lecturer guidance. In the final stage, the students showed the results of their project work after revisions. The following are the final results produced by high-ability, medium-ability, and low-ability students (as shown in Figs. 7, 8, and 9, respectively) for the concept of the definition of a circle.

High-ability students (see Fig. 7) had been able to design a good GeoGebra application to express the definition of a circle. Based on the GeoGebra output, the students demonstrated that the distance of one center point, point O, to a given point was the same as the distance to another point; the distance from O to A1, the distance from O to A2, the distance from O to A3, the distance from O to A4, and so on, were the same. All points that were equidistant to point O would together form a circle. The results obtained by high-level students indicated that independent learning provided them with experiences to develop higher-order thinking and express it clearly [32, 57].

Students of medium ability were also able to develop a GeoGebra application for explaining the definition of a circle. As shown in Fig. 8, they had provided a button to form an infinite number of points equidistant to point O. Meanwhile, students of low ability had made a GeoGebra application to express the definition of a circle (Fig. 9), but the points created could not show a circle shape clearly. This was because they were unable to perform reasoning in establishing concepts and understanding problems.

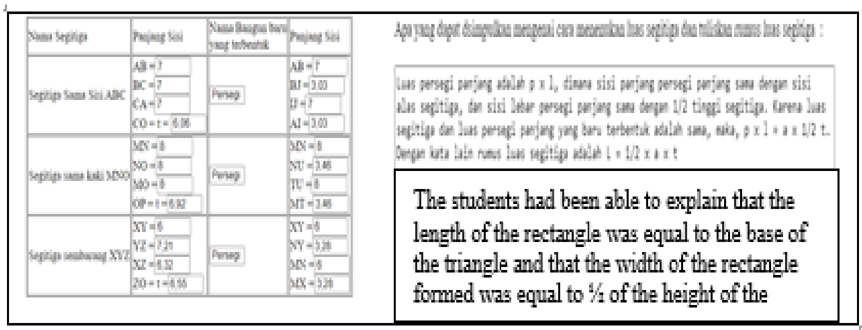

Fig. 5. GeoGebra output data processing for the concept of the area of a triangle.

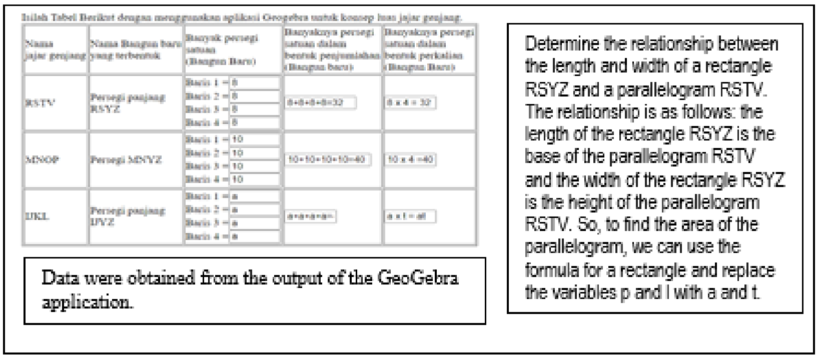

Fig. 6. GeoGebra output data processing for the concept of the area of a parallelogram.

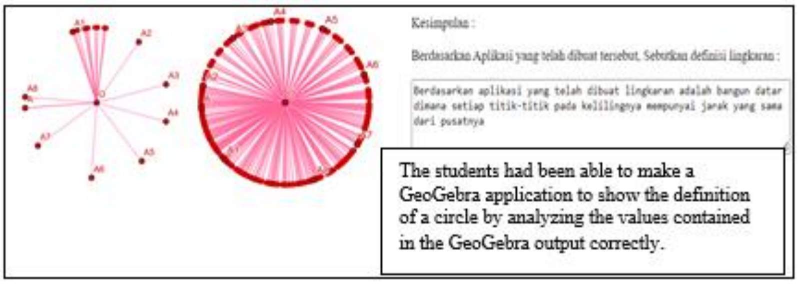

Fig. 7. The result of the project produced by high-ability students.

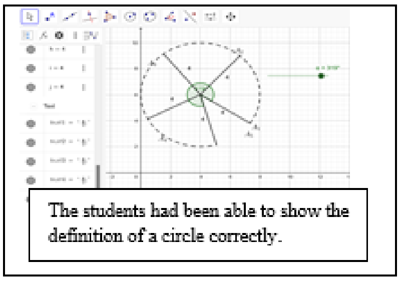

Fig. 8. The Result of the project produced by medium-ability students.

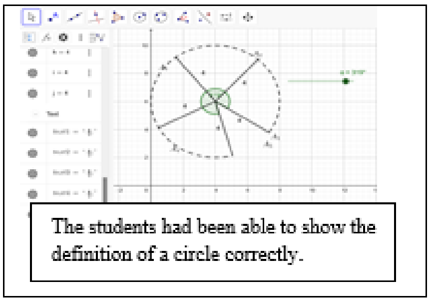

Fig. 9. The result of the project produced by medium-ability students.

3.6. Preparation of reports and presentations

Other GeoGebra applications were also produced by the students to determine the length of a common internal tangent to two circles. They made the GeoGebra applications by providing an input field to fill in the radial lengths of a large circle and a smaller circle. They were able to identify regularities and patterns to determine the length of the common internal tangent to two circles, as can be seen in Fig. 10.

The students determined some patterns and regularities to be able to determine the length of the common internal tangent to two circles. By using the right triangle formed, triangle MNO, the length of the common internal tangent to two circles, AB, could be determined using the Pythagorean theory. The process of finding concepts that consist of determining relationships, comparing regularities, finding patterns, and generalizing shows that inductive reasoning has a central role in developing thinking and complex problem-solving skills [4, 9]. The ability of the students to design and complete the project showed that the students were of different levels of innovation and creativity. Research results have shown that the web-based PjBL model could enable students to use their thinking and creativity skills to solve problems to date [59].

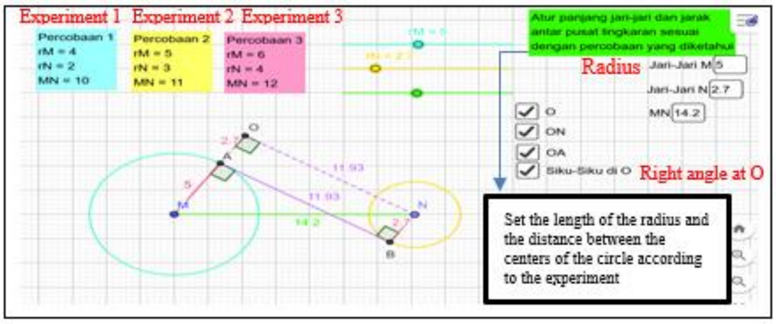

Fig. 10. The GeoGebra application produced for the concept of the length of the common internal tangent to two circles.

4. Conclusion

This research produced learning trajectories and helped students solve problems through project-based activities, as were proven through the activities carried out during the research. The students' first activity was designing online GeoGebra applications. The second activity, which was conducted over the web, was performing inductive reasoning by observing regularities and patterns that were formed based on the output of the GeoGebra applications. The third activity was making generalizations to understand the concepts of the area of a triangle, the area of a parallelogram, the area of a trapezoid, the definition of a circle, and the length of a common internal tangent to two circles.

References

1. Molnár, G.; Greiff, S.; and Csapó, B. (2013). Inductive reasoning, domain specific and complex problem solving: Relations and development. *Thinking Skills and Creativity*, 9, 35-45.

2. Söderqvist, S.; Nutley, S.B.; Ottersen, J.; Grill, K.M.; and Klingberg, T. (2012). Computerized training of non-verbal reasoning and working memory in children with intellectual disability. *Frontiers in Human Neuroscience*, 6, 271.
3. Christou, C.; and Papageorgiou, E. (2007). A framework of mathematics inductive reasoning. *Learning and Instruction*, 17(1), 55-66.
4. Mokmin, N.A.M.; and Masood, M. (2015). The development of self-expressive learning material for algebra learning: An inductive learning strategy. *Procedia-Social and Behavioral Sciences*, 197, 1847-1852.
5. Wu, H.; and Molnár, G. (2018). Interactive problem solving: assessment and relations to combinatorial and inductive reasoning. *Journal of Psychological and Educational Research*, 26(1), 90-105.
6. Rott, B. (2021). Inductive and deductive justification of knowledge: epistemological beliefs and critical thinking at the beginning of studying mathematics. *Educational Studies in Mathematics*, 106(1), 117-132.
7. Arslan, C.; Göcmencelebi, S.I.; and Tapan, M.S. (2009). Learning and reasoning styles of pre service teachers': inductive or deductive reasoning on science and mathematics related to their learning style. *Procedia-Social and Behavioral Sciences*, 1(1), 2460-2465.
8. Hamers, J.H.M.; De Koning, E.; and Sijtsma, K. (1998). Inductive reasoning in third grade: Intervention promises and constraints. *Contemporary Educational Psychology*, 23(2), 132-148.
9. Mousa, M.; and Molnár, G. (2020). Computer-based training in math improves inductive reasoning of 9-to 11-year-old children. *Thinking Skills and Creativity*, 37, 100687.
10. Perret, P. (2015). Children's inductive reasoning: Developmental and educational perspectives. *Journal of Cognitive Education and Psychology*, 14(3), 389-408.
11. Soeharto, S.; and Csapó, B. (2022). Assessing Indonesian student inductive reasoning: Rasch analysis. *Thinking Skills and Creativity*, 46, 101132.
12. Rivera, F.D.; and Becker, J.R. (2007). Abduction-induction (generalization) processes of elementary majors on figural patterns in algebra. *The Journal of Mathematical Behavior*, 26(2), 140-155.
13. Vainikainen, M.P.; Hautamäki, J.; Hotulainen, R.; and Kupiainen, S. (2015). General and specific thinking skills and schooling: Preparing the mind to new learning. *Thinking Skills and Creativity*, 18, 53-64.
14. Soeharto, S.; and Csapó, B. (2022). Assessing Indonesian student inductive reasoning: Rasch analysis. *Thinking Skills and Creativity*, 46, 101132.
15. Rohmawati, T.; and Winata, H. (2021). Information technology for modern marketing. *International Journal of Research and Applied Technology (INJURATECH)*, 1(1), 90-96.
16. Adebayo, A.E.; and Ochayi, O.A. (2022). Utilization of internet services among students of polytechnic institutions in Kwara State. *Indonesian Journal of Multidiciplinary Research*, 2(1), 27-42.
17. Thapwiroch, K.; Kumlue, A.; Saoyong, N.; Taprasan, P.; and Puengsungewan, S. (2021). Easy-mushroom mobile application using the Internet of Things (IoT). *Indonesian Journal of Educational Research and Technology*, 1(2), 1-6.

18. Fadillah, P. Nandiyanto, A.B.D.; Kurniawan T.; and Bilad, M.R. (2022). Internet literature: Increasing information competence in the learning process of students of class 7 middle school. *Indonesian Journal of Educational Research and Technology*, 2(2), 81-86.
19. Soegoto, E.S.; Soegoto, H.; Soegoto, D.S.; Soegoto, S.W.; Rafdhi, A.A.; Saputra, H.; and Oktafiani, D. (2022). A systematic literature review of internet of things for higher education: Architecture and implementation. *Indonesian Journal of Science and Technology*, 7(3), 511-528.
20. Lolos, A.M.; Etrata, A.A.; Gonzales, K.C.I.; Lipura, M.B.; and Abusam, H.P. (2022). Decoding the metaphor of humor: Understanding why Filipino cybernauts cannot stop clicking on internet memes. *ASEAN Journal of Community Service and Education*, 1(2), 117-120.
21. Pantjawati, A.B.; Purnomo, R.D.; Mulyanti, B.; Pawinanto, R.E.; and Nandiyanto, A.B.D. (2020). Water quality monitoring in citarum river (Indonesia) using iot (internet of thing). *Journal of Engineering, Science and Technology*, 15(6), 3661-3672.
22. Derr, K.; Hübl, R.; and Ahmed, M.Z. (2018). Prior knowledge in mathematics and study success in engineering: informational value of learner data collected from a web-based pre-course. *European Journal of Engineering Education*, 43(6), 911-926.
23. Jonsdottir, A.H.; Bjornsdottir, A.; and Stefansson, G. (2017). Difference in learning among students doing pen-and-paper homework compared to web-based homework in an introductory statistics course. *Journal of Statistics Education*, 25(1), 12-20.
24. Karagiannis, P.; Markelis, I.; Paparrizos, K.; Samaras, N.; and Sifaleras, A. (2006). E-learning technologies: employing Matlab web server to facilitate the education of mathematical programming. *International Journal of Mathematical Education in Science and Technology*, 37(7), 765-782.
25. Noroozi, O.; Busstra, M.C.; Mulder, M.; Biemans, H.J.; Tobi, H.; Geelen, A.; Veer, P.V.; and Chizari, M. (2012). Online discussion compensates for suboptimal timing of supportive information presentation in a digitally supported learning environment. *Educational Technology Research and Development*, 60(2), 193-221.
26. Novianti, W.; and Erdiana, E. (2021). Information technology to support e-advertisement. *International Journal of Research and Applied Technology (INJURATECH)*, 1(1), 134-139.
27. Bakar, N.S.A.; Maat, S.M.; and Rosli, R. (2020). Mathematics teacher's self-efficacy of technology integration and technological pedagogical content knowledge. *Journal on Mathematics Education*, 11(2), 259-276.
28. Dias, B.L.B. (1999). Integrating technology. *Learn Lead with Technol*, 27(3), 10-14.
29. Muhtadi, D.; Wahyudin, Kartasasmita, B.G.; and Prahmana, R.C.I. (2018). The Integration of technology in teaching mathematics. *Journal of Physics: Conference Series*, 943(1), 1-8.
30. Barak, M. (2012). From ‘doing’to ‘doing with learning’: Reflection on an effort to promote self-regulated learning in technological projects in high school. *European Journal of Engineering Education*, 37(1), 105-116.

31. Putri, R.I.I.; Setyorini, N.P.; Meitrilova, A.; Permatasari, R.; Saskiyah, S.A.; and Nusantara, D.S. (2021). Designing a healthy menu project for Indonesian junior high school students. *Journal on Mathematics Education*, 12(1), 133-146.
32. Han, S.; Capraro, R.M.; and Capraro, M.M. (2016). How science, technology, engineering, and mathematics project-based learning affects high-need students in the US. *Learning and Individual Differences*, 51, 157-166.
33. Rahayu, P.T.; and Putri, R.I.I. (2021). Project-based mathematics learning: Fruit salad recipes in junior high school. *Journal on Mathematics Education*, 12(1), 181-198.
34. Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, 83(2), 39-43.
35. King, B.; and Smith, C. (2020). Using project-based learning to develop teachers for leadership. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 93(3), 158-164.
36. Hopper, S.B. (2014). Video conferencing and PBL. *Tech Trends*, 58(3), 78-89.
37. Bilgin, I. (2015). The effects of project-based learning on undergraduate students' achievement and self - efficacy beliefs towards science teaching. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(3), 469-477.
38. ChanLin, L.J. (2008). Technology integration applied to project-based learning in science. *Innovations in Education and Teaching International*, 45(1), 55-65.
39. Erdogan, Y.; and Dede, D. (2015). Computer assisted project-based instruction: The effects on science achievement, computer achievement and portfolio assessment. *International Journal of Instruction*, 8(2), 177-188.
40. Appiah-Kubi, P.; Johnson, M.; and Trappe, E. (2019). Service learning in engineering technology: Do students have preferences on project types?. *Journal of Engineering Technology*, 36(1), 32-41.
41. Pattier, D. (2021). Science on youtube: Successful edutubers techno review. *International Technology, Science and Society Review*, 10(1), 1-15.
42. Owens, A.D.; and Hite, R.L. (2022). Enhancing student communication competencies in STEM using virtual global collaboration project-based learning. *Research in Science and Technological Education*, 40(1), 76-102.
43. Radović, S.; Radojičić, M.; Veljković, K.; and Marić, M. (2020). Examining the effects of Geogebra applets on mathematics learning using interactive mathematics textbook. *Interactive Learning Environments*, 28(1), 32-49.
44. Arbain, N.; and Shukor, N.A. (2015). The effects of GeoGebra on student's achievement. *Procedia-Social and Behavioral Sciences*, 172, 208-214.
45. Takači, D.; Stankov, G.; and Milanovic, I. (2015). Efficiency of learning environment using GeoGebra when calculus contents are learned in collaborative groups. *Computers and Education*, 82, 421-431.
46. Reis, Z.A.; and Ozdemir, S. (2010). Using Geogebra as an information technology tool: Parabola teaching. *Procedia-Social and Behavioral Sciences*, 9, 565-572.

47. Aris, R.M.; and Putri, R.I.I. (2017). Design study: integer subtraction operation teaching learning using multimedia in primary school. *Journal on Mathematics Education*, 8(1), 95-102.
48. Atkinson, P.; Delamont, S.; Cernat, A.; Sakshaug, J.; and Williams, R.A. (2021). *SAGE Research Methods Foundations*. Sage Publications.
49. Spelt, E.J.H.; Luning, P.A.; van Boekel, M.A.; and Mulder, M. (2015). Constructively aligned teaching and learning in higher education in engineering: what do students perceive as contributing to the learning of interdisciplinary thinking?. *European Journal of Engineering Education*, 40(5), 459-475.
50. Putri, R.I.I.; and Zulkardi. (2017). Fraction in shot-put: A learning trajectory. *AIP Conference Proceedings*, 1868 (1), 050005.
51. Blumenfeld, P.C.; Soloway, E.; Marx, R.W.; Krajcik, J.S.; Guzdial, M.; and Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, 26(3-4), 369-398.
52. Putri, R.I.I.; and Zulkardi, Z. (2019). Designing jumping task on percent using pmri and collaborative learning. *International Journal on Emerging Mathematics Education*, 3(1), 105-116.
53. Obeid, M.A.; and Azer, M.K. (2015). Pan-African adakitic rocks of the north Arabian-Nubian Shield: petrological and geochemical constraints on the evolution of the Dokhan volcanics in the north Eastern Desert of Egypt. *International Journal of Earth Sciences*, 104(3), 541-563.
54. Sosa Moguel, L.E.; Aparicio Landa, E.; Cabañas-Sánchez, G. Characterization of inductive reasoning in middle school mathematics teachers in a generalization task. *International Electronic Journal of Mathematics Education*, 14(3), 563-581.
55. Hanum, L. (2017). Improving mathematics achievement of indonesian 5th grade students through guided discovery learning. *Journal on Mathematics Education*, 8(1), 77-84.
56. Cañadas, M.C.; and Castro, E. (2007). A proposal of categorisation for analysing inductive reasoning PNA. *Revista de Investigación en Didáctica de la Matemática*, 1(2), 67-78.
57. Evans, R.; Friedman, J.; McGrath, L.; Myers, P.; and Ruiz, A. (2018). Math path: Encouraging female students in mathematics through project-based learning. *Primus*, 28(4), 287-299.
58. Bills, L.; and Rowland, T. (1999). Examples, generalisation and proof. *Research in Mathematics Education*, 1(1), 103-116.
59. Holmes, V.L.; and Hwang, Y. (2016). Exploring the effects of project-based learning in secondary mathematics education. *The Journal of Educational Research*, 109(5), 449-463.