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Enhancing mathematical literacy ability through guided inquiry learning with augmented reality

Heni Pujiastuti[1] ✉
Rudi Haryadi[2]


(✉ Corresponding Author)

[1]*Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia.*
Email: henipujiastuti@untirta.ac.id
[2]*Department of Physics Education, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia.*
Email: rudiharyadi@untirta.ac.id

Abstract

Mathematical literacy is important for students to formulate, use and interpret mathematics in various contexts. The aim of this research is to determine the effectiveness of Guided Inquiry Learning-Augmented Reality (GILAR) on mathematical literacy ability. This research method used a quasi-experimental pretest and posttest design with a non-equivalent control group. The pretest and posttest questions are in the form of a description of the material in the geometry. The subjects of this study were 30 experimental class students and 30 control class students i.e. 15 males and 15 females. In the experimental class, GILAR is used while in the control class direct instruction learning is used. The results showed that GILAR was more able to improve students' mathematical literacy skills than direct instruction learning. The results of the N-gain show that the experimental class produced 58.88% while the control class was 45.77%. Based on these results, learning by using GILAR can improve mathematical literacy skills in junior high school students. This study recommended using augmented reality in the school mathematics curriculum to address the students' mathematical literacy. Furthermore, it needs to conduct a similar study at the university level. Then, to respond to the COVID -19 outbreaks, it is necessary to implement augmented reality.

Keywords: Augmented reality, Direct instruction learning, Guided inquiry learning, Junior high school, Mathematical literacy.

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Contents

Contribution of this paper to the literature
This study contributed to the use of augmented reality in the school mathematics curriculum to address the students' mathematical literacy. Furthermore, this study has produced interactive learning at the school level. However, this augmented reality can also be used outside of the school such as in the students' homes.

1. Introduction

Education is an essential thing for the establishment of a developed country (Stalvey et al., 2019). Education is not just a medium to transmit culture to the next generation. Still, education is expected to change and establish national life patterns for the better (Zaslavsky, 2019). The quality of a nation or country's human resources can certainly be determined with by its educational system (Mason, 2019). Nations with high-quality human resources will be more advanced and able to compete with other nations (Tsai, 2019). Education is a term that cannot be separated from learning activities (Knuth, Zaslavsky, & Ellis, 2019).

Learning in formal schools provide provisions for students in various fields (Fang & Chapman, 2020). Informal schooling in the field of mathematical science is one of the scientific fields that students will receive (Genlott & Grönlund, 2016). Mathematical literacy focuses on reasoning, thinking and interpretation in addition to other abilities (Hidayat, Zamri, Zulnaidi, & Yuanita, 2020). Mathematical literacy is closely related to the real world. Therefore, people are required to understand the role of mathematics in real life and use it to solve problems associated with the context of everyday life (Zikl, Havlíčková, Holoubková, Hrníčková, & Volfová, 2015). Correspondingly, it also involves converting problems from the real world into mathematical forms or vice versa, namely interpreting an outcome or mathematical model into the original problem (Collins & Laski, 2019). Mathematical literacy skills can also shape the character of students needed to respond to challenges in the globalization era today (Roth, Ercikan, Simon, & Fola, 2015). To be an efficient student, one must have mathematical literacy skills (Sumirattana, Makanong, & Thipkong, 2017).

One material that often involves mathematical literacy skills is material about geometry. Geometry material provides approaches to solve problems such as drawings, angles, lines and so on (Yang, Stief, Dantan, Etienne, & Siadat, 2019). Geometry occupies a special position in the mathematics curriculum because of the many concepts involved (Madra, Breitkopf, Raghavan, & Trochu, 2018). It is a very strategic mathematical study that encourages learners to appreciate and experience mathematics by learning it more meaningfully (Sutiarso & Coesamin, 2018).Geometry help students in understanding the concepts of numbers and measurement through optical properties and representations (Zimmerling, Poppe, & Kärger, 2020). School geometry has a great opportunity to be understood by students compared to other branches of mathematics (Vidermanova & Vallo, 2015). From an early age, students have learned the introduction of basic geometry concepts such as learning geometric shapes (Denizli & Erdogan, 2018).

This study aims to improve mathematical literacy skills by applying the Guided Inquiry Learning-Augmented Reality (GILAR) learning model. Based on the results of the previous studies, mathematical literacy can be addressed with the right learning model (Cameron, Kim, Duncan, Becker, & McClelland, 2019). We need a good learning model to improve the quality of education. The learning model is a learning design with a different atmosphere (Pujiastuti, Utami, & Haryadi, 2020); (Steinberger, 2020). A teacher will easily complete the learning as planned so that learning will be more effective (Sad, 2020). So, the creative learning model can foster students' mathematical literacy abilities (Purpura, Schmitt, & Ganley, 2017).

Students are given the freedom to determine problems to be investigated, find and solve problems independently and design procedures or steps needed. Guided inquiry learning is a model activity consisting of observations, asking questions, reviewing books and other sources of information to review something that is already known and plan an investigation. In addition, review something known based on the results of an experiment, use tools or devices to collect, analyze and interpret data, propose answers, explanations and estimate and present the results (Decker-Lange, 2018). The inquiry requires that someone recognizes their assumptions, think critically, logically, and consider alternative explanations (Suarez, Specht, Prinsen, Kalz, & Ternier, 2018).

Augmented reality has entertainment that can heighten students' interest in learning, playing, projecting it as real and involving the interaction of all five senses of students with this augmented reality technology (Cahyono, Sukestiyarno, Asikin, Ahsan, & Ludwig, 2020). It is because augmented reality has characteristics and functions that are almost the same as learning media.

Augmented reality is beneficial for interactive and real-world learning media and is used directly by students (Yip, Wong, Yick, Chan, & Wong, 2019). It is interactive which makes students see the real situation directly and imagine the results of the actual learning process given by educators (Pujiastuti & Haryadi, 2020).

This research sought to provide a deeper understanding of how learning humanistic mathematics can improve the character of junior high school students. This research focuses on class VIII students, who are on average age of 13 and constructivist mathematics learning. Problem-solving that can improve mathematical literacy skills as well as provide information for teachers about the treasury of science, especially the study of mathematical literacy skills and characters that are integrated into the process of learning mathematics geometry and measurement materials, especially in the cube, blocks, prisms and pyramid.

2. Materials and Methods

The purposive sampling technique was used in this study's quasi-experimental design. Furthermore, the research design uses a non-equivalent control group design using two classes: the experimental class consisted of 30 students and the control class consisted of 30 students (Dick, Carey, & Carey, 2001). The experimental class used Guided Inquiry Learning-Augmented Reality (GILAR) learning while the control class used Direct Instruction Learning (DIL) (see Figure 1).

Before being given treatment, students in each class are first given a test to ensure their initial ability (pretest). At the end of the study, students were also given a posttest. This test serves to see the results of students' mathematical literacy abilities. This study seeks to answer the question, "is there any impact of the Guided Inquiry Learning-Augmented Reality on ability of mathematical literacy?"

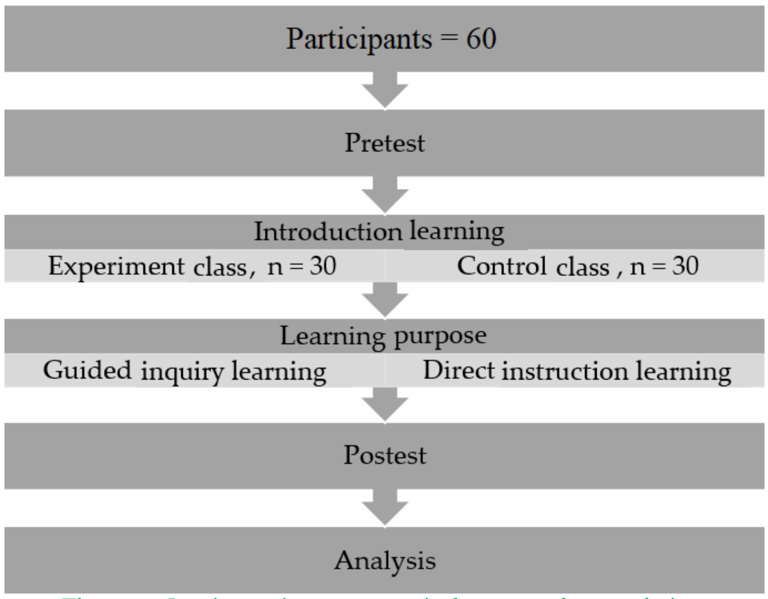

Figure 1. Quasi-experiment non-equivalent control group design.

Based on Figure 1, all middle school students in Serang City, Banten province, Indonesia were given a pretest question in the first week. The material given is a matter of geometry related to mathematical literacy abilities. It is done to know the initial abilities of students regarding their mathematical literacy. In the second week, all students are given a calm understanding of the importance of learning objectives from the geometry material. Furthermore, students are divided into two classes, namely the experimental class and the control class. Each class consists of 30 students i.e. 15 male and 15 female. From the third week to the seventh week, learning is carried out in accordance with the grouping of each class. The experimental class is the class that gets the treatment of the GILAR model while the control class is the class that does not get the treatment or gets it with DIL learning. In the eighth week, posttest activities were carried out. This is done to determine the final results of learning by using the GILAR model and DIL. Furthermore, the data in the form of pretest and posttest values that have been obtained, then analyzed by calculating the normalized gain (n-g). This is done with the aim to find out the magnitude of changes in students' mathematical literacy skills or how much influence the use of the GILAR model has on mathematics literacy abilities. Normalized gain is the proportion of actual gain (test-initial-test-end) to the maximum gain obtained. The gain formula is as follows (Hake, 1998):

$$n - g = \frac{x_{post} - x_{pre}}{x_{max} - x_{pre}} \quad (1)$$

Explanation:
n-g = n-gain
x_{pre} = pretest score
x_{post}= posttest score
x_{max}= maximum score
The n-gain coefficient is interpreted using the criteria that can be seen in Table 1.

Table 1. N-gain coefficient Criteria (Hake, 1998).

N-gain coefficient	Classification
$0 \leq$ n- g < 0.3	Low
$0.3 \leq$ n-g < 0.7	Medium
$0.7 \leq$ n-g < 1	Height

3. Results

The data on students 'mathematical literacy abilities described in this study consisted of their ' initial mathematical literacy abilities obtained from the pretest and their final mathematical literacy abilities obtained from the posttest. In mathematics, literacy ability data, pretest scores are used to describe students' mathematical literacy abilities before being given treatment in research. Posttest scores were used to describe students' mathematical literacy abilities after being given treatment in the study. Furthermore, the pretest and posttest values obtained n-gain values to illustrate the magnitude of the effect after doing the learning model in research. The following data is the mathematical literacy ability of junior high school students in Serang city, Banten province, Indonesia, on geometry material using the GILAR and DIL models presented in Figure 2.

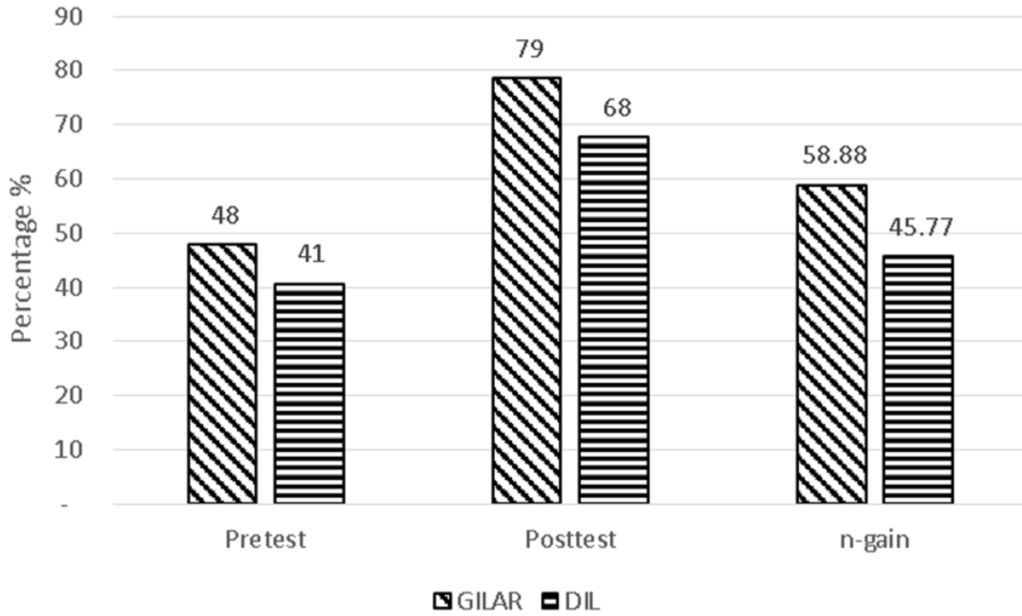

Figure 2. Comparison of n-gain between GILAR and DIL models.

In Figure 2, it appears that the average n-gain for the experimental group using the GILAR model is higher than the average n-gain of the control group using the DIL model. It shows that the use of Guided Inquiry Learning Augmented Reality (GILAR) can further improve the mathematical literacy of junior high school students compared to Direct Instruction Learning (DIL). The difference between the n-gain scores between the experimental class using the GILAR model and the control class using the DIL model shows that the average n-gain score of the experimental class using the GILAR model is 58.88. It belongs to the medium category while the control class using the DIL model of 45.77 also includes the medium category. Based on these data, it can be seen that from the two classes tested, there was an increase in the average results of students' mathematical literacy abilities on geometry material but when viewed the results, the GILAR model was higher 13.11 than the DIL model. So, learning in the experimental class using the GILAR model is more effective than learning in the control class using the DIL model.

In the GILAR model, the teacher presents problems by connecting real-life phenomena with the subject being studied by students, namely geometry. In the stage of formulating the problem, the teacher displays the augmented reality media related to the material being studied to raise questions. The teacher provides the problem formulation for the augmented reality media that has been shown previously. In applying the GILAR model, students are given the opportunity to work on formulating procedures, analyzing results and drawing conclusions independently while in terms of determining topics, questions and supporting materials, the teacher is only a facilitator. Previous research findings support the effectiveness of GILAR in this study. The inquiry learning model emphasizes student activity (Stockdale, Hughes, Stronge, & Birch, 2019). Other research results also state that the free inquiry learning model can provide freedom and opportunities for students to explore by gathering facts through observation or experimental activities to arouse students' interest and curiosity about the concepts being studied (Suarez et al., 2018).

So, it can be said that the GILAR model can create an intellectual confrontation in each student. Learning objects or the environment can be used to bring up facts or other symptoms that allow students to question the solution (Rohaeti, Bernard, & Primandhika, 2019). Furthermore, the direct instruction learning model can build learning models in specific fields of study (Pacanowski & Levitsky, 2020). The teacher can show how a problem can be approached, how information is analyzed and how knowledge is generated (Martyn et al., 2020). Furthermore, the mathematical literacy ability of students by gender of male students can be seen in Figure 3.

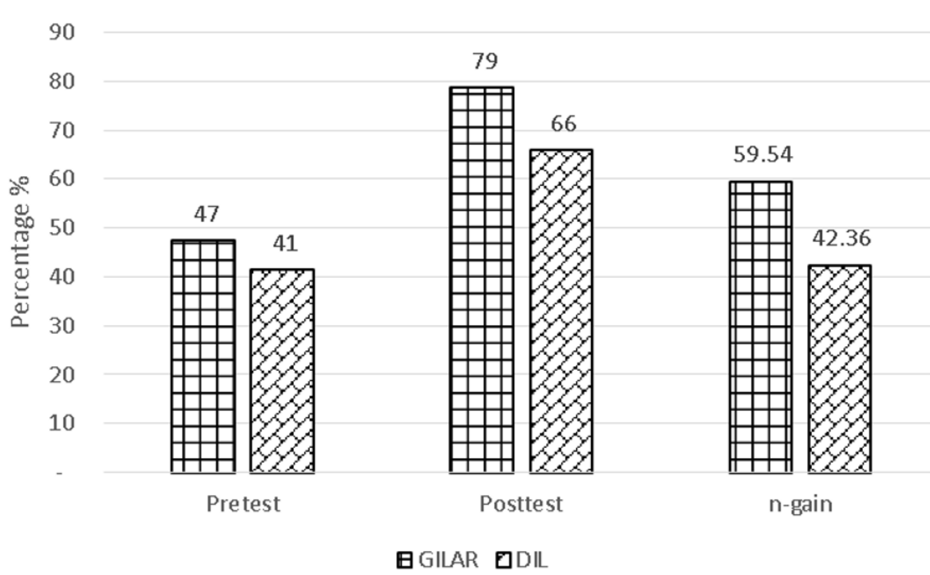

Figure 3. Comparison of n-gain of GILAR and DIL groups from 15 male students.

Figure 3 shows that the average n-gain from 15 male students in the Guided Inquiry Learning Augmented Reality (GILAR) group can further improve mathematical literacy skills in 15 male junior high school students compared to Direct Instruction Learning (DIL). This can be seen from the n-gain value obtained from the GILAR learning model treatment of 59.54 and the n-gain value obtained from the treatment of the DIL model of 42.36. So it can be said that the GILAR model is more effectively used on 15 male students than using the DIL model on 15 male students. Furthermore, mathematical literacy skills for female students can be seen in Figure 4.

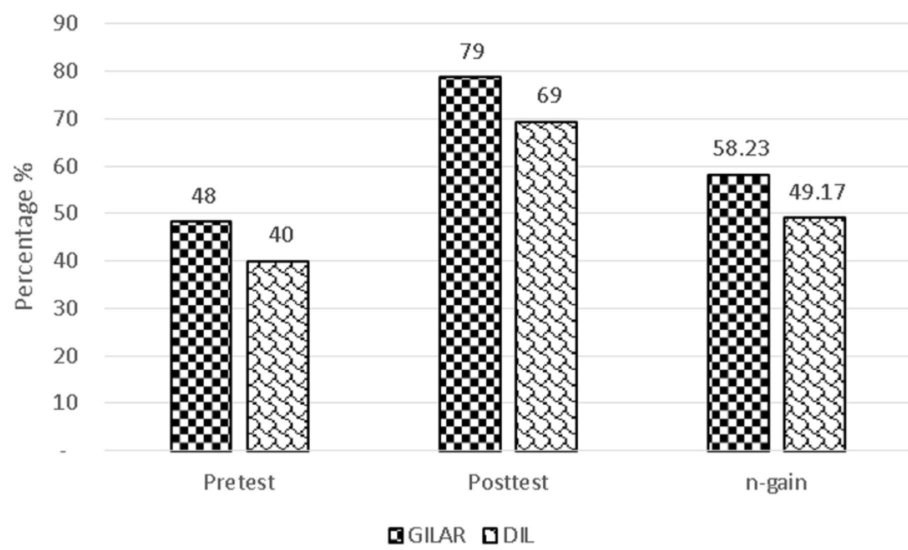

Figure 4. Comparison of n-gain of GILAR and DIL groups in 15 female students.

In Figure 4, the average n-gain in 15 females for the Guided Inquiry Learning Augmented Reality (GILAR) group can further improve mathematical literacy skills in 15 female junior high school students compared to Direct Instruction Learning (DIL). It can be seen from the n-gain value obtained due to the treatment of the GILAR learning model of 58.23and the n-gain value obtained due to the treatment of the DIL model of 49.17. So it can be said that the GILAR model is more effectively used on 15 female students than using the DIL model on 15 female students.

Furthermore, the mathematical literacy ability of students based on gender differences for 15 male students and 15 female students can be seen in Figure 5.

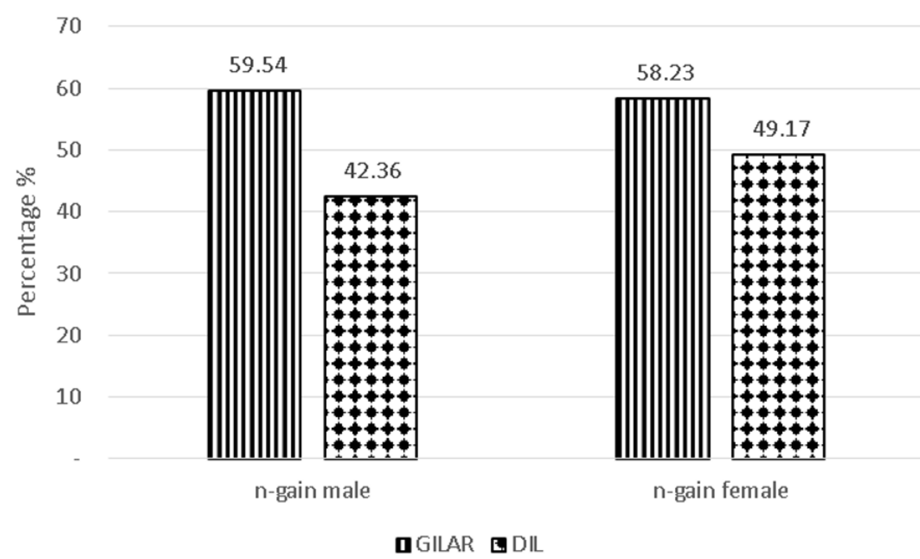

Figure 5. Comparison of n-gain of GILAR and DIL groups based on gender differences.

In Figure 5, the average n-gain based on gender differences shows that the effect of using the GILAR learning model does not differ much between men and women. The results from using the GILAR model are still higher than the DIL model. But if you only see the effect of DIL learning, the mathematical literacy ability 15 women is higher than that of 15 men. It can be seen from the value of n-gain of 15 male students obtained due to the treatment of the GILAR model by 59.54. At the same time, the value of n-gain for the 15 female students was obtained due to the treatment of the GILAR model by 58.23. But the results in Figure 5 show that the DIL model is more effective against 15 female students than against 15 male students. It can be seen from the n-gain value of 15 female students obtained due to the treatment of the DIL model of 49.17, while the n-gain value of 15 male students obtained due to the treatment of the DIL model is 42.36.

Furthermore, the abilities of each aspect of student mathematical literacy can be seen in Figure 6.

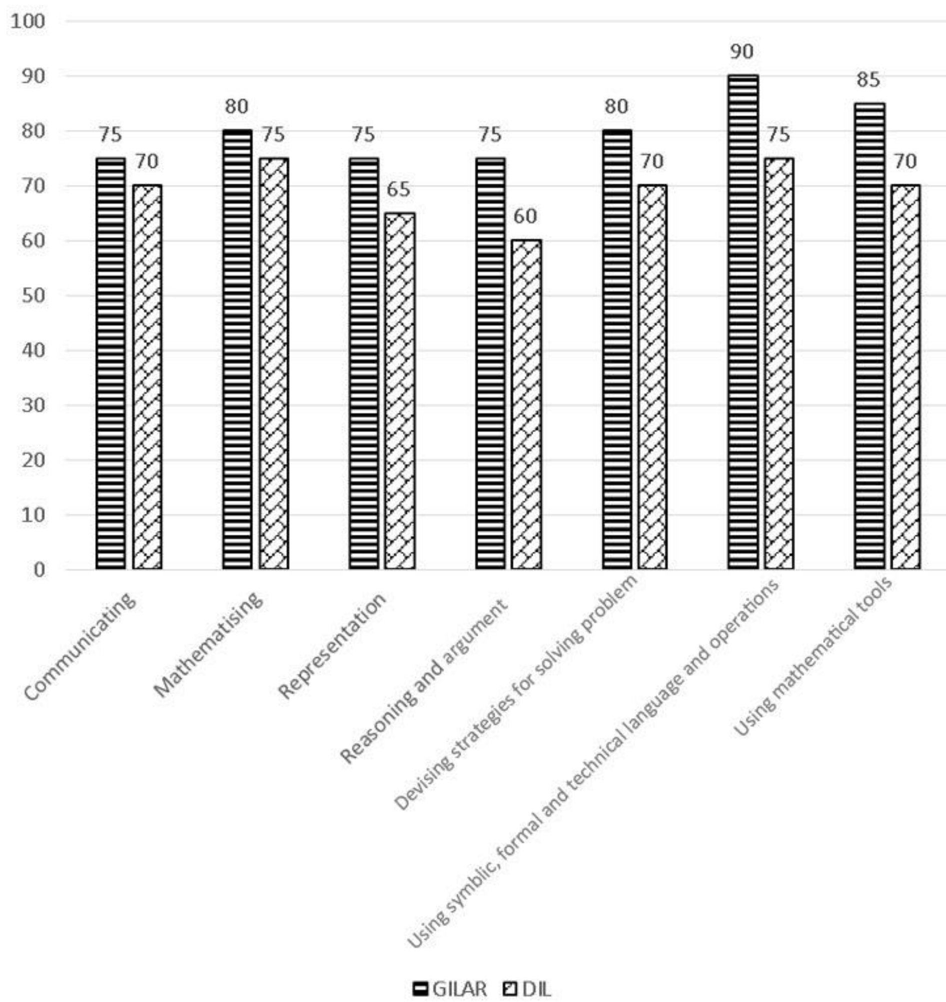

Figure 6. Results of students' mathematical literacy abilities from every aspect.

In Figure 6, it can be seen that the ability of students 'mathematical literacy resulting from the treatment of the GILAR model is greater than the ability of students' mathematical literacy produced by the treatment of DIL models. So, it can be said that the GILAR model is more effective in improving mathematics literacy skills in junior high school students than using the DIL model.

4. Discussion

Mathematical literacy involves communication. In this aspect, each student feels a change and is designed to recognize and understand problem situations, read, decode and interpret statements, questions, assignments, or objects that may lead to mental shapes and situations that require important steps to understand, clarify and formulate a problem. During the settlement process, interim results need to be clarified or presented. Furthermore, the solution has been found. Solving the problem requires providing may need to provide a solution and perhaps an explanation or proof or something else.

Mathematical literacy can involve solving realistic problems in the form of mathematics. The word "mathematizing" is used to describe things related to mathematical activities. At this stage, students can already describe the basic mathematical activities involved in transforming problems that are defined in everyday life into mathematical form (which includes structure, concepts, making assumptions, and or formulating models), interpreting, evaluating mathematical results or developing mathematical models about contextual problems.

Mathematical literacy requires reasons and arguments to solve it. In this aspect, students already have the logic of explaining and connecting elements of the problem to draw conclusions from the problem. Furthermore, in this aspect, students can already check and justify what is given and the statement or solution to the problem.

Mathematical literacy requires the discovery of strategies to solve mathematical problems. This collection of critical processes is categorized as selecting, discovering or planning strategies using mathematics. In this aspect, students can recognize problems effectively and apply formulas and solve problems arising from an assignment or context.

Mathematical literacy requires the ability to use mathematical tools. Mathematical tools are physical tools such as measuring and calculating tools as well as computer-based tools whose existence is wider. This ability includes knowledge about the use of various tools in mathematical activities and knowledge about approaches to the use of these tools. In this aspect, students can already use augmented reality as a mathematical tool to understand geometry concepts.

Furthermore, when students studied geometry material, this study discovered new findings. The ability of students is indicated by the results of their work which show that: (1) students can interpret the comparison of two quantities. (2) Students can associate with the concept of the circumference of a circle. (3) Students can find the wide-area concept. (4) Students can associate the concept of an equivalent comparison. (5) Students have not been able to find correctly estimates. (6) Students can manipulate the concrete object models given the problem through assumptions and experiments. (7) Students can transform geometric shapes to find the equivalent area requested by the problem. (8) Students can state the steps of completion using sentences or sketches of images. (9) Students can carry out procedures for finding linkages with the concept of the Pythagorean theorem. (10) Students can interpret problems and use certain representations in the form of sketches.

5. Conclusions

Based on the results and discussion above, the Guided Inquiry Learning Augmented Reality (GILAR) model can further enhance students' mathematical literacy skills than the Direct Instruction Learning (DIL) model. This study recommended using augmented reality in the school mathematics curriculum to address the students' mathematical literacy. Furthermore, it needs to conduct a similar study at the university level. Then, to respond to the COVID -19 outbreaks, it is necessary to implement augmented reality. Furthermore, this study has produced interactive learning at the school level. However, this augmented reality can also be used outside of the school such as in the students' homes.

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