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Implementation of Project-Based Learning (PjBL) Assisted by Geogebra Application to Improve Students' Spatial Abilities

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ABSTRACT

The purpose of this study was to determine whether the implementation of the Geogebra-assisted Project Based Learning (PjBL) model has an impact on improving students' spatial abilities or not. Quantitative method with experiments was used in this study. The sample used was class B and C students of Mathematics Education IAIN Kudus class of 2022/2023 who were selected through cluster random sampling techniques. To determine the level of effectiveness, pretest and posttest instruments were given to students. Before the instrument was given, content, construct, and item tests were carried out. Based on the content validation test given by two experts, a V-Aiken score of 0.93 was obtained, which was categorized as very valid. Furthermore, item tests were carried out, which included item validity tests, discrimination power, level of difficulty, and reliability. Based on the analysis of the item test, it was stated that all questions could be used. The effectiveness test was carried out using N-Gain, and an average score of 3.896 was obtained, categorized as moderate. From these calculations, it is concluded that PjBL learning models assisted by the Geogebra application have a positive impact on improving students' spatial abilities.

KEYWORDS

Project-Based Learning (PjBL)
Geogebra Application
Spatial Ability

1. Introduction

Human life is influenced by the important role of education. Education provides opportunities for humans to broaden their horizons and gain knowledge (Lanani, 2015; Mikrayanti, 2016) . The process of broadening horizons is obtained through learning in the scope of formal and non-formal education. One of the learning emphasized in education is mathematics learning. Mathematics plays an important role in preparing the next generation to face the challenges of globalization, especially in the era of technological reform (Sofiyah et al., 2025). Husnul Fauzan & Khairul Anshari (2024) added that mathematics learning helps students to think logically in the problem-solving process. In addition, Kristia, Habibi, Fidya, & Putra (2021) also explained that mathematics learning can hone students' perseverance, hard work, and thoroughness in a job. Attitudes and skills that are part of the quality of human life are influenced by the implementation of mathematics learning.

Behind the importance of learning mathematics, it turns out that there are many problems in learning mathematics that must be resolved immediately. Mathematics is considered an abstract, difficult to understand and boring subject (Hasibuan, Siti Yuliana; Hasybi, Aliya Nur; Siregar, Ary Yantyi; Sofiyah, 2025). Furthermore, Muslimin & Sunardi (2019) explained that students still have difficulty understanding concepts in geometry material. Muslimin & Sunardi (2019) also explained that this difficulty is because students do not understand the basic terminology in geometry concepts. Students' difficulties in learning geometry material were also found by Saputra & Fahrizal (2019) . Saputra & Fahrizal (2019) explained that in learning geometry material, conventional learning is still used, so it does not provide an overview of geometry concepts for students. Therefore, learning geometry material requires media that students can use to understand the material easily.

The presence of media in mathematics learning has an influence on the success of the teaching and learning process that occurs in formal education.. This is because learning media helps the process of delivering material optimally by teachers to students (Wicaksono, 2016) . Wicaksono's statement (2016) is closely related to the function of learning media, namely as a channel of messages that can stimulate the thoughts, feelings, and desires of students to be involved in the learning process (Luh &

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Ekayani, 2021) . In addition, Maharani, Arita Selly; Nasuhaa, Salsa Umi; Maulida (2024) explained that learning media helps teachers create effective, non-monotonous learning conditions and motivates them to continue learning. With these various advantages, it can be concluded that learning media helps maximize the learning process and contributes to improving the quality of education (Kozma, 1994) .

One of the materials taught by teachers to students is geometry. In order to provide meaningful learning to students on geometry, improve students' understanding and learning outcomes on geometry, teachers' ability to develop learning media is highly emphasized to support the optimization of the mathematics learning process. This demand also applies to students of the Mathematics Education study program as prospective mathematics teachers. Students' skills in developing these media are included in pedagogical competence, where the role of information and communication technology can be maximized by a teacher in supporting the learning process (Depdikbud, 2005) . The skills of Mathematics Education students as prospective mathematics teachers in developing learning media are emphasized as an effort to maximize the learning process.

In addition to being useful in maximizing school learning on geometry material, the ability to develop learning media can also improve students' spatial abilities. Spatial ability is the ability that focuses on the representation of three-dimensional or more objects (Sudirman & Alghadari, 2020). Spatial ability allows abstract mathematics to become more visual and real (Asryana, Sanapiah, & Kinasih, 2017) . To create learning media on geometry material, students are required to create visualizations of an object and analyze it. Through the creation of this learning media, students will be trained to improve their spatial abilities.

As an effort to help students develop learning media and also improve their spatial abilities, the GeoGebra application can be used. Hohenwarter (2008) explained that Geogebra is a computer program that can be used for free and helps the learning process of geometry, calculus, and algebra in mathematics through easy-to-use software. One of the benefits of the Geogebra application is as a demonstration and visualization media, as a construction aid, as a discovery aid, and as a communication and representation tool (Hohenwarter & Fuchs, 2004). Through the Geogebra application, students find it easier to create visuals of a form that can be represented on a learning media. With clear visualization, it can also help students understand geometry material through the learning media that is developed. This is also in line with NCTM (2000) which explains that the purpose of geometry material in schools is so that students can use shape visualizations in solving problems. The Geogebra application helps students create shape visualizations that can be used in creating learning media for geometry material.

As an effort to equip students to improve their spatial abilities, PjBL learning model is carried out. Surya et al., (2018) explained that the PjBL model emphasizes the learning process based on a project. In addition, the learning model also prioritizes contextual thinking from complex activities (Andrianis et al., 2018). The PjBL learning model can accustom students to think complexly based on the existing context. The PjBL learning model can help students improve their spatial abilities through abstract characteristics in geometry material.

Based on the study that has been described, the researcher took the initiative to implement the Project Based Learning (PjBL) learning model assisted by the Geogebra application on learning media to improve the spatial abilities of students in the Mathematics Education study program. There are several previous studies that are relevant to this study, including research by Ummah et al. (2019) . Unlike that study, this study uses the PjBL model. In addition, the study used students as research subjects, while in the other study used students as subjects. In addition, there is a study by Usmeldi (2019) . This study is also different from this study. This study was specifically conducted on improving students' spatial abilities, while in that study, it was only mentioned in general on student learning outcomes. In addition, the subjects in this study were also different from those in the previous study. It is hoped that the novelty in this study can contribute to the field of mathematics education. More specifically, it is hoped that this study can prepare Mathematics Education students to be more competent in preparing their abilities as prospective mathematics teachers.

2. Method

Quantitative methods were used in this study. This is because the main objective of this study is to determine the level of effectiveness of the implementation of the PjBL model assisted by the Geogebra application on students' spatial abilities. A quasi-experimental design was carried out in this study in the form of using a one-group pretest-posttest experiment. Before the treatment was given, all students were given a pretest of mathematical spatial abilities. Students were also given a posttest of mathematical spatial abilities after being given treatment. To determine the increase in students' spatial abilities, the development of test instruments was also carried out, which were given before and after treatment to students.

Before the pre-post test of spatial mathematical ability was given to students, content validity was verified. Content validity was provided by two validators who were lecturers in the field of mathematics education. The following is the V aiken formula used (1) (Aiken, 1885):

$$V = \frac{\sum s}{m(c-1)} \dots (1)$$

Description:
V : Rater agreement index regarding item validity
s : The score assigned by the rater minus the lowest score in the category used
m :Many questions
c : There are many categories for raters to choose from.
Next step is to determine the level of validity based on the content validation that has been calculated using the following V aiken (Retnawati, 2016):

Table 1. Validity Criteria

Indeks Aiken (V)	Criteria
V > 0,8	Very Valid / High Validity
0,4 < V ≤ 0,8	Medium
V ≤ 0,4	Less Valid

In addition to conducting overall content validation, each question item was also tested. The test includes the test of item validity, discriminatory power, level of difficulty, and reliability. The test of item validity was conducted using Karl Pearson product moment correlation with the formula (2) (Taherdoost, 2018):

$$r_{xy} = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{\{N\sum X^2 - (\sum X)^2\}\{N\sum Y^2 - (\sum Y)^2\}}} \dots (2)$$

The validity of the question items is determined by comparing the calculated r (*product-moment*) with the r-table. If $\boldsymbol{r_{xy}} \geq r_{tabel}$ it is, then the question items can be used. If it does not meet these criteria, then the question items cannot be used.

After the question is declared usable, the next step is to analyze the question's discrimination power. using the formula (3) (Asrul; Ananda, 2014):

$$D = \frac{\overline{X_a} - \overline{X_b}}{SMI} \dots (3)$$

Description :
D = Discriminant Power
$\overline{X_a}$ = Average score of the upper group
$\overline{X_b}$ = Average score of the lower group
SMI : Ideal maximum score
A classification was then carried out using the following criteria (Ebel & Frisbie, 1991):

Table 2. Criteria for the Distinguishing Power
The questions used are questions that are good $D > 0{,}30$ and categorized as good.

Distinguishing Power	Question Criteria
$< 0{,}20$	Ugly and unacceptable
$0{,}20 - 0{,}30$	enough and needs improvement
$> 0{,}30$	Good and acceptable

In addition to the discrimination power of the questions. The level of difficulty of the questions can be known through calculations using the following formula (4) (Sudjiono, 2016):

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$$TK = \frac{\overline{X}}{SMI} \ldots (4)$$

Description :

TK : Difficulty level

$\overline{X}$: Average value for each question item

SMI : Ideal Maximum Score

The level of difficulty is then categorized through the classification:

Table 3. Criteria for the Level of Difficulty of Question Items

Difficulty Level	Question Criteria
0,00 – 0,30	Difficult
0,31 – 0,70	Medium
0,71 – 1,00	Easy

The final item test conducted was the *Cronbach alpha reliability test* using the following formula (5) (Taherdoost, 2018):

$$r_i = \frac{k}{(k-1)}\left\{1 - \frac{\sum S_i^2}{S_t^2}\right\} \ldots (5)$$

Description:

k : Number of questions

$\sum S_i^2$: The amount of variance of scores for each question item

S_t^2 : Total variance

Front enterpretations are then carried out based on the following criteria:

Table 4. Reliability Criteria for Question Items

Cronbach's Alpha	Information
r < 0.20	Very low reliability
$0,20 \leq r < 0,40$	Low reliability
$0,40 \leq r < 0,70$	Moderate reliability
$0,70 \leq r < 0,90$	High reliability
$0,90 \leq r < 1,00$	Very high reliability

If the results of the reliability test are obtained $> 0{,}60$, then an instrument is said to be reliable. Likewise, if the results are $< 0{,}60$, then it is said to be unreliable.

After conducting validity tests on the overall test items, the discriminating power of the questions, the level of difficulty, and reliability, the next step is to conduct a posttest on students. The posttest was conducted after being given treatment in the form of PjBL model learning with the help of the Geogebra application. From the posttest score, a hypothesis test will be conducted using a paired t-test using SPSS 26. However, before conducting a paired t-test, a normality and homogeneity test was conducted as a requirement. Finally, an effectiveness test was conducted to determine the level of effectiveness of the implementation of the Geogebra-assisted PjBL model in improving students' spatial abilities using the following formula:

$$N\ Gain = \frac{skor\ postest - skor\ pretest}{skor\ ideal - skor\ pretest} \ldots (5)$$

The level of effectiveness can be determined using the following criteria (Meltzer, 2002):

Table 5. N-Gain Criteria

N-Gain Value	Category
$g > 0{,}7$	High
$0{,}3 \leq g \leq 0{,}7$	Currently
$g < 0{,}7$	Low

Learning activities using the PjBL model assisted by Geogebra are said to be effective if the N-gain value is in the medium or high category.

Students of the Mathematics Education study program of IAIN Kudus, class of 2022/2023 are the population used in this study. The number of classes involved is three classes, namely classes A, B, and C. In determining the research sample, the cluster random sampling technique was used, and two classes were obtained, namely classes B and C. Meanwhile, class A was used for testing the students' spatial mathematical ability test instrument in developing learning media before being given to classes B and C.

3. Results and Discussion

3.1 Research Process

This study was conducted by implementing the PjBL model assisted by the Geogebra application on learning media to improve the spatial abilities of Tadris Matematika students. In the implementation process, it was found that there was an increase in students' spatial abilities after the Geogebra-based learning media creation project was carried out through PjBL and learning media expo activities. The first step taken in this study was to develop a student spatial ability test instrument. The instrument was then tested for content validation by two experts. After being declared valid, the researcher conducted a trial to prove the construct validity, item validity, discrimination power test, and difficulty level test. The questions that met the criteria in each test were then tested for reliability. After the instrument was declared valid and reliable, data was collected regarding students' spatial mathematical abilities before the creation of the learning media project through the PjBL model. The next step is to apply the PjBL model assisted by Geogebra to the peak activity, namely the learning media expo. The last step in this study was to provide a posttest to students to find out the results after being exposed to the PjBL model assisted by Geogebra on their spatial abilities.

There are several steps in the PjBL model according to experts. Some of the steps in the PjBL model include determining the project, planning project completion steps, preparing a project implementation schedule, completing the project with teacher monitoring, preparing reports and presentations of project results, and project evaluation (Anggraini & Wulandari, 2020) . From these steps, they were then generalized in this activity into steps to ask questions, create project designs, create schedules, monitor project progress with FGDs, and expo activities, assessments, and project evaluations. These steps are in line with the steps in the following PjBL model:

3.1.1 Asking Questions: in this step, students are required to identify problems that arise in learning geometry material at school. The problem identification process is found in previous research and based on interview results. Based on the problems found, students then hold group discussions to find effective solutions through media and teaching aids.

3.1.2 Creating Project Design: in this step students are required to create a design for media and teaching aids as a solution to the existing problems. Several tools, materials, or other needs needed to create media and teaching aids are also determined at this stage. Several other essential things are also discussed at this stage, including the product name, product usefulness, and how the product works are also carried out.

3.1.3 Making a Schedule: to realize the creation of media and teaching aids, at this stage a production schedule is formulated up to the final and evaluation stages.

Fig 1. Project Schedule Creation Activities

3.1.4 Monitoring Student Project Progress through FGD: this step is taken to see the progress of media and teaching aids creation by students. In this step, the lecturer also gives students the opportunity to convey the difficulties experienced during the process of creating media and teaching aids. From these various difficulties, an FGD was then conducted and it was agreed to utilize the Geogebra application to help students create visualizations of shapes to support the creation of media.

Fig 2. FGD Project Creation Activities

3.1.5 Expo, Result Assessment, and Experience Evaluation: this step facilitates students to exhibit the media and props that have been created. The expo is held openly and attended by the public. This stage also evaluates group work, both individually and in groups.

3.2 Content Validation Proof)

This content validation was conducted with the aim of measuring the suitability between the theory and the material and language aspects of the test instrument. There were two validators who provided an assessment of the validity of the instrument. The following are the results of the content validation test by experts, calculated using V Aiken:

Table 6. Content Validation Results

Grain	ASSESOR		S1	S2	∑s	$n\,(c-1)$	V	Ket
	Rater 1	Rater 2						
B_1	4	4	3	3	6	6	1	High
B_2	4	4	3	3	6	6	1	High
B_3	4	3	3	2	5	6	0.83	High
B_4	4	3	3	2	5	6	0.83	High
B_5	4	4	3	3	6	6	1	High
			Average				0.93	High

Based on Table 3, each test item has a high Aiken V index level. On this basis, the test items can be said to be valid and can be used for a trial test of students' spatial mathematical abilities in making media and teaching aids. Based on the validator's suggestion, the test items can be used for a trial without revision.

3.3 Construct Validation Proof

Construct validation is used to determine the indicators in mathematical spatial ability used in instruments to measure students' mathematical spatial ability. To prove the validity of this construct, a confirmatory factor analysis is carried out *with* the help of Lisrel. Precisely, the first-order factor analysis is used because this validity proof only uses one-level latent variables, namely mathematical spatial ability based on several observed variables such as spatial visualization, spatial orientation, and spatial relations.

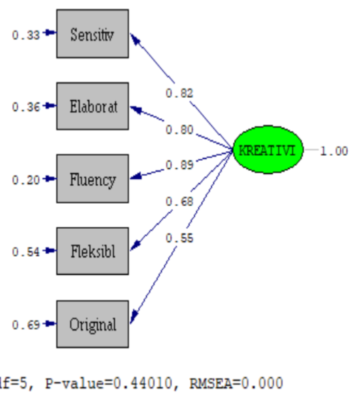

Fig 3. Construct of Mathematical Spatial Ability Theory

The standard model is shown in Figure 3. Equipped with factor loads (path coefficients from variable to variable) that are quite high to very high (sequentially starting from the spatial relation variable to spatial orientation and spatial visualization, namely 0.33, 0.47, and 0.69. This is in accordance with Retnawati (2016) who explained that the path coefficient is meaningful if the magnitude of the factor load is not less than 0.4. This condition indicates that the latent variable gets quite a lot of support from all observed variables. The latent variable in this case is the spatial ability of students. In addition, the model in Figure 3 is a suitable model because the p-value = 0.44> 0.05 and the RMSEA is close to 0 or less than 0.08. This is based on the model suitability criteria (goodness of fit) by Schermelleh-Engel et al. (Schermelleh-Engel, Moosbrugger, & Müller, 2003). This finding shows that students are said to have the ability good spatial mathematics in making mathematical media and teaching aids.

3.4 Proof of Validity of Question Items

The validity of a test can be interpreted as the extent to which a test can measure what it should measure (Utomo, 2019) . The validity test of the question items can be interpreted as the extent to which the prepared questions can measure students' spatial abilities. The validity of these questions uses the *Karl Pearson Product-Moment formula*. The results of the validity test:

Table 7. Results of Question Item Validation

Criteria	Many Questions	Question Number	Information
$r_{xy} \geq r_{tabel} = 0{,}3961$	5	1,2,3,4,5	Can be used
$r_{xy} < r_{tabel} = 0{,}3961$	-	-	Not used

Based on Table 5, $r_{tabel} = r_{0{,}05;25-2} = r_{0{,}05;23} = 0{,}3961$ it was found that of the 5 question items that were declared valid because they had $r_{xy} \geq 0{,}3961$. Thus, the five question items can be used to measure students' spatial mathematical abilities.

3.5 Discriminant Power

According to Arikunto in Solichin (2017) , According to Arikunto in Solichin (2017), getting an idea of the abilities of students with high and low abilities is the main objective of conducting a discrimination power test. The procedure for testing this discriminatory power is to sort the highest score to the lowest score of students and then divide 27% into the upper group and 27% into the lower group. The results of the instrument trial analysis can be seen in the table:

Table 8. Results of Differential Power of Question Items

Index Discriminant	Many Questions	Question Numer	Information
D ≤ 0.30	-	-	Not used
D > 0.30	5	1,2,3,4,5	Good and usable

Based on the table, it is found that the five questions have a good discriminant index because they are in the D> 0.3 interval. The five questions can be used to collect data on the pre and post-test.

3.6 Difficulty Level

The difficulty level test was conducted to determine the level of the test items. In this study, only medium and high levels were used. The following are the calculation results using SPSS:

Table 9. Results of the Level of Difficulty of Question Items

Difficulty Level	Manu Questions	Question Numer	Information
$TK \leq 0{,}30$	-	-	-
$0{,}31 \leq TK \leq 0{,}70$	1	5	Used
$TK > 0{,}70$	4	1,2,3,4	Used

From the table above, it can be seen that question number 5 is in the medium criteria and questions number 1,2,3, and 4 are in the high criteria. Thus, the five questions can be used to measure students' spatial abilities.

3.7 Reliability Estimation

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The purpose of the reliability test is to ensure that the measuring instrument used has consistent results, even though it has been used repeatedly, and is reliable (Anshari, Nasution, Irsyad, Alifa, & Zuhriyah, 2024) . This reliability test uses the *Cronchbach's alpha* formula and the following results are obtained:

Table 10. Reliability Estimation Results

Reliability Statistics	
Cronbach's Alpha	N of items
0, 850	5

From the SPSS calculation above, it can be seen that the result obtained is 0.850, which is stated as reliable.

3.8 Classical Assumption Test

Before the data of students' spatial mathematical ability were analyzed using a paired t-test, a normality test and a homogeneity test were previously conducted as prerequisite tests. The normality test used the Shapiro Wilk Test on the pretest and posttest data with the help of SPSS 26. The test was used because the research sample was relatively small. From the normality test, the values were obtained $P_{value} = 0{,}013 \geq 0{,}01 = \alpha$on the pretest and $P_{value} = 0{,}122 \geq 0{,}01 = \alpha$posttest. From both values, the decision was made that Ho was accepted. This means that the pretest and posttest groups are in a normal distribution. The homogeneity test of the pretest and posttest data groups was carried out using the Lavene test with the help of SPSS 26 and the value was obtained $P_{value} = 0{,}142 \geq 0{,}01 = \alpha$. From these values, the decision was made that Ho was accepted and the data was homogeneous.

3.9 Hypothesis Testing

The following are the results of the paired t-test as a continuation after the data was declared normal and homogeneous, calculated using SPSS:

Table 11. Paired t-Test Results

Group		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre	65.4800	50	5.40876	0.76491
	Post	84.0500	50	5.03787	0.71246

It is known from Table 11. that the average value obtained by students in the posttest is greater than the average value obtained in the pretest. Furthermore, a paired t-test was conducted as a hypothesis test. From the paired t-test, it was obtained $P_{value} = 0{,}000 < 0{,}01 = \alpha$ in the pretest and posttest groups. Therefore, the value P_{value}less than α, then Ho is rejected. This means that there is a statistically significant difference between students' spatial abilities before and after the implementation of the Geogebra-assisted PjBL model.

The effectiveness test was conducted after conducting a paired t-test. The following are the calculation results using SPSS:

Table 12. N-Gain Results

Indicator of spatial abilities	Pretest Mean	Posttest Mean	Difference	N Gain
Spatial Perception	2,996	3,608	0.612	0.610
Spatial Visualization	2,864	3.36	0.496	0.437
Mental Rotation	2,696	3.12	0.424	0.325
Spatial Relations	2,396	2.94	0.544	0.339
Spatial Orientation	2.192	2.62	0.428	0.237

If the average calculation is carried out, the average N-Gain is 0.3896 which is categorized as moderate.

There is a significant difference in the average value shown by students who have been given PjBL learning models with the help of Geogebra and those who have not in the research results. The average value of students after the PjBL learning model assisted by Geogebra is higher than before the learning. This means that PjBL learning models assisted by Geogebra can improve students' spatial abilities. In addition, based on the N-Gain value, it was also found that the effectiveness of the implementation of PjBL learning models assisted by Geogebra was categorized as moderate. The results of the N-Gain value indicate that the implementation of PjBL learning models assisted by Geogebra has a positive impact on students' spatial mathematical abilities.

The process of creating learning media on geometry material supported by the PjBL model in the learning process can foster students' innovation and collaboration skills. Before developing media, students are required to identify several things needed by students and teachers in learning mathematics, especially in geometry material. Not only that, the ability to think actively to find solutions to problems is also trained by students through this process. The learning process also encourages students to think critically in exploring various existing problems. From the problems provided, students can develop innovative creativity as an alternative solution offered. The PjBL model with the FGD method also provides students with the opportunity to provide suggestions for media and teaching aids developed as solutions to the needs of learning geometry material. With various skills honed through this learning, it can improve student learning outcomes. This is also in line with the research of Nurhayati, Zuhra, & Salehha (2021) which found an increase in student learning outcomes through the application of the PjBL learning model.

Learning with the PjBL model allows for simultaneous learning of theory and practice, resulting in meaningful learning for students. Through PjBL learning, students' knowledge will be stimulated through a series of activities that they have done. This will create a sense of being and support the achievement of learning objectives (Amelia & Aisya, 2021) . In addition, the use of the PjBL model is also supported by the theories of Piaget and Vygotsky which emphasize that a person's knowledge will develop if someone gains experience related to the knowledge learned and has developed previous knowledge (Amelia & Aisya, 2021) . PjBL model learning also begins with problems that make it easier for students to know the implementation of concepts to solve problems, so that the process of understanding the concept will be easier (Anggraini & Wulandari, 2020) . So, the implementation of the PjBL model in learning will provide students with an understanding of the application of mathematical concepts in solving problems based on their experiences. This understanding will make it easier for students as prospective mathematics teachers to provide understanding to students regarding the material that has been studied.

In addition to involving the PjBL model, this learning also involves Geogebra media which helps students understand the material being studied and helps improve their spatial abilities. Geogebra media helps students understand abstract mathematical concepts and is used as a basis for creating learning media. This is also supported by Simbolon (2020) who explains that one of the functions of Geogebra is to provide a visual depiction to provide an understanding of abstract mathematics. With this visual depiction, students not only find it easy to understand the meaning of a particular concept, but also allow students to analyze the characteristics of a particular shape or concept. The results of this analysis and understanding will be a provision for students to teach students later. In addition, Geogebra can also provide a more varied and attractive appearance (Simbolon, 2020) . With these characteristics, it will provide a fun and not boring learning atmosphere for students. Geogebra helps students understand a mathematical concept in a fun and not boring way.

The results of this study support the statement that the implementation of the Geogebra-assisted PjBL model has a positive impact on students' spatial abilities. Guven & Kosa in Sudirman & Alghadari (2020) define spatial ability as a person's ability to understand and create a mental image in the form of shape and space. Through the Geogebra application, students will know the image of a shape or space more clearly. Abstraction in mathematics can also be understood through the image. Indirectly, the use of the Geogebra application helps students imagine an abstract shape to be more real and has a positive impact on their spatial abilities. This is also supported by Rostina, T, & Simin (2021) who wrote in their research results that using the Geogebra application can improve students' spatial abilities. Through this understanding, students can easily create learning media that will be used in teaching practices at school. Through the PjBL model, students are not only required to understand the concept of shape in mathematics, but can also create learning media that is a manifestation of their understanding. So, the implementation of the PjBL model assisted by the Geogebra application provides students with a better understanding of the material being studied and can be used as a support in developing learning media.

Behind the several advantages that have been described, this study still allows for development. In this study, only an analysis was carried out based on external factors in influencing students' spatial mathematical abilities. The analysis carried out in this study did not include internal factors that also have the potential to influence each other on students' spatial mathematical abilities. Therefore, based on this description, it is necessary to develop an analysis related to several factors that influence students' spatial abilities, both internally and externally. Through this study, it is also possible to develop learning using the PjBL model based on the characteristics and needs of students. This statement is also in line with Larraz-Rábanos (2021) who stated that in the learning process, not only the curriculum and learning models are considered, but psychological conditions also need to be given special attention to support the learning process using the chosen model. This learning process requires lecturers to continuously develop insights and provide learning that is appropriate for students. In addition, assignments given by lecturers must also be able to require students to think critically, be skilled in solving problems, and be able to make connections between the material being studied and future needs. These are some of the things that underlie researchers to take a relatively small research sample.

In this study, not only was the effectiveness test conducted on the implementation of the PjBL model to support the improvement of students' spatial mathematical abilities, but also produced learning media that can be used by students for teaching practice in schools. Thus, learning is not only oriented towards theoretical learning, but also involves practice-based learning that leads to meaningful learning. Thus, it is hoped that the implementation of the PjBL model assisted by Geogebra can also be applied to other courses in order to maximize learning objectives.

In addition, this learning also involves the Geogebra application to help students understand the material. The involvement of the Geogebra application through digital media can provide students with an understanding that learning does not always utilize a whiteboard or conventional media, but can integrate technology. Integration of technology in mathematics learning can increase learning efficiency and help students' understanding of the material being taught. It is hoped that through this learning, students will be more creative in choosing media as a support in the mathematics learning process.

4. Conclusion

The implementation of the PjBL model has proven effective in improving students' spatial abilities in learning activities assisted by the Geogebra application. This can be seen from the statistically significant difference between students' spatial mathematical abilities after and before intervention. In addition, the value of students' spatial mathematical abilities after intervention was 84.05 and before intervention 65.48 . This indicates an increase in students' spatial mathematical abilities in developing mathematics learning media after being exposed to media expo activities through the PjBL model. The researcher hopes that this research can encourage other researchers to apply other innovative learning to improve students' spatial abilities.

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