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DEVELOPMENT OF GEO-MATH APPLICATION BY INTEGRATING GEO-GEBRA APPLETS TO IMPROVE STUDENTS' SPATIAL ABILITY

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Abstract

Geometry can be challenging for students due to its abstract nature; The difficulty is often associated with low spatial abilities; to overcome these challenges, educators can employ dynamic and visual learning approaches to help students learn and understand geometric concepts more effectively. This study aimed to develop a Geo Math application by integrating the GeoGebra applets on geometry that fulfill valid, practical, and effective aspects that are expected to improve spatial abilities. This research utilized development research using the ADDIE model, which consists of 5 stages: analysis, design, development, and trial implementation. It went through several trial stages consisting of validation experts, one-to-one trials, and small group trials, and the evaluation stage was carried out through a pre-post-test quasi-experimental study. Based on the results, it can be concluded that the Geo Math application was very feasible to support the implementation of learning mathematics, especially in learning geometric transformations, which could assist students in constructing concepts from various transformations effectively. The interactive and dynamic nature of GeoGebra applets within the application allowed students to visualize and manipulate geometric objects and could make abstract mathematical concepts more concrete and accessible, which could improve students' spatial abilities.

Keywords: *Android-Based Learning Media; Geogebra Applets; Spatial Abilities.*

A. Introduction

The integration of technology in education has significantly transformed teaching and learning. Technology plays a crucial role in transforming traditional learning environments into interactive and collaborative systems. The use of innovative technologies has revolutionized the way students learn and teachers teach, enhancing the overall educational experience (Haleem et al., 2022; Meisuri et al., 2023). As an innovative learning medium, technology is believed to be able to increase the efficiency and effectiveness of learning (Bergdahl et al., 2020). The implementation of technology-based learning media in learning can greatly enhance the learning experience in understanding various concepts (Maulidia et al., 2023; Purwasari & Purnamaningsih, 2022), particularly in subjects like mathematics that involve abstract concepts such as geometry. Geometry is a branch of mathematics that deals with the study of shapes, sizes, and properties of objects in space. It involves understanding spatial relationships, angles, shapes, and transformations, which can be abstract concepts to grasp without a clear mental image. This causes many students to struggle to visualize geometric objects (Alghadari et al., 2020; Ismail et al., 2020), which can make it challenging for them to solve various geometric problems. In line with previous research, many students had difficulty understanding geometry material (Naidoo & Kapofu, 2020; Nurjanah & Juliana, 2020).

Students' difficulties in understanding geometry material can be caused by various factors. According to Mastura et al. (2022), students' difficulties in understanding geometry are due to the abstract nature of the material; besides, the effectiveness of learning resources and media in supporting the learning process is less interesting, especially in learning geometry transformation. In addition, Siswanto (2016) stated that low spatial abilities can also significantly contribute to students' difficulties in understanding geometry. Spatial abilities involve the capacity to visualize, manipulate, and reason about objects and their relationships in space (Lowrie et al., 2019). Wang and Carr (2020) explain that spatial ability generally refers to the ability to represent and manipulate two-dimensional or three-dimensional images. Spatial ability has an important role in learning mathematics, especially in geometry. In the context of the

curriculum (Ferrini-Mundy, 2000), spatial ability is one of the demands that must be accommodated in learning mathematics. This shows that students' spatial abilities need to be continuously improved to assist them in learning mathematics. Therefore, teachers need to maximize the use of learning resources and media that are more varied and interactive to assist students in improving their spatial abilities. The utilization of information and communication technology (ICT) as a learning medium can be a solution to assist students in learning geometry, which requires high spatial abilities (Kim & Irizarry, 2021). Various studies have shown that the use of technology in learning, such as the GeoGebra application (Sugiarni et al., 2018; Suprapto et al., 2021) and Augmented reality (AR) applications (Papakostas et al., 2021), can be used to improve students' spatial abilities. In addition, Armstrong (2002) and Collins (2017) also mentioned that presenting material visually by utilizing technology-based media is an effort to help students improve their spatial abilities. This shows that the use of technology-based media in learning mathematics, especially geometry material, can be a solution to improve students' spatial visualization abilities.

One of the technological media that can be used as a learning medium is an Android-based smartphone. Several previous studies have developed various Android-based learning applications, both of which can be operated on a computer or laptop with the Windows operating system and on a Smartphone (Ennouamani et al., 2020; Puspitasari & Wahyudi, 2022; Triayomi & Pamugkas, 2023). Some other studies have also developed Android-based mathematics learning media designed for dynamic and interactive geometric constructions, such as the Android-based Augmented Reality application, which contains flat shape material and builds space for the AR camera to display markers on books (Widyaastuti & Suwanto, 2022), the Android-based mathematics learning game containing various geometry images and questions (Aisyah et al., 2021; Suddin & Deda, 2020), and the geometry mobile learning application (Muliyana et al., 2024). The application consists of several features, including interactive live worksheets, instructional videos, GeoGebra, Google Forms, and Quizizz. GeoGebra in the mobile learning geometry application is

used to help students understand given problems and demonstrate the properties of spatial structures. This shows that there's a wide range of Android apps designed to assist students in learning mathematics, especially geometry. However, most of the available applications only consist of learning materials packaged in the form of Android applications containing various images, videos, and games. Likewise, the use of GeoGebra in Android learning applications as a tool for enhancing the learning experience in geometry is also limited. Learning applications that can provide opportunities for students to independently create dynamic geometric constructions in an interactive learning environment to help students visualize geometric objects are still limited. Therefore, it is necessary to provide an Android-based learning application that can be used to assist students in visualizing geometric objects in a dynamic and interactive learning environment.

Researchers are interested in developing Android-based learning applications by integrating the GeoGebra Applets, which aims to maximize efforts to visualize geometric objects. GeoGebra applet is a GeoGebra file extension (ggb.) or output that has been designed based on learning needs. According to Radović et al. (2020), by using the GeoGebra Applet that has been designed by the teacher, students can recognize and review the properties of certain objects, focus on mathematical characteristics, and analyze the relationship between mathematical concepts and geometric objects. Furthermore, the use of GeoGebra Applets in interactive environments such as in the classroom can help students transition from procedural to conceptual knowledge in mathematics (Radović et al., 2020; Luna et al., 2022). Wassie and Zergaw (2019) also explained that the use of GeoGebra Applets in learning helps students to be actively involved in learning activities. GeoGebra applets with various math topics have been created and distributed on GeoGebra's Material site, which can be accessed free of charge. Several studies have also developed various GeoGebra Applets, such as the GeoGebra Applet for quadratic function material (Paoletti et al., 2017), the GeoGebra Applet for quadrilateral material (Nisiyatussani et al., 2018), and the GeoGebra Applet for triangular material (Radović et al., 2020).

However, accessing GeoGebra applets designed by teachers and researchers can sometimes be challenging due to various factors such as availability, compatibility, or lack of proper sharing platforms. To make it easier for teachers and students to access the GeoGebra Applets, an application that can accommodate the applets that have been designed is needed. Therefore, the researchers developed the Geo Math application, which integrates the GeoGebra applet specifically for geometric transformations. In this research and development, the researchers designed the GeoGebra Applets related to various geometric transformation concepts. The GeoGebra Applets are designed based on the needs of high school students and aim to support the development of mathematical ideas while at the same time constructing mathematical concepts.

Thus, the main objective of this research is to develop an Android-based learning medium, namely the Geo Math application, by integrating the GeoGebra Applets specifically for geometric transformations for high school students. Therefore, the focus of this research problem is: What is the process and results of developing Geo Math Application by integrating GeoGebra Applets on geometry material for high school students that is valid, practical, and effective based on the assessment of media experts, material experts, teachers, and high school students.

B. Method

The method employed in this research is research and development (R&D). According to Richey and Klein (2014), research and development is a systematic study consisting of a design, development, and evaluation process that is aimed at creating or improving products, services, or processes.

1. Research and Development Procedures

The stages of the research carried out refer to the ADDIE development model (Branch, 2009), which consists of 5 stages, as explained below:

The analysis phase aimed to find out whether the development of the Geo Math application is needed by high school students to learn geometry. In this phase, the researchers analyzed the teachers' and students' need for

Android-based learning media, curriculum analysis, as well as analysis of teachers and students as users.

The design phase is a stage of designing the application based on the requirements and information gathered during the analysis phase. In this phase, the researchers designed the concept and content of the Geo Math application to be developed.

The development phase is a stage of design realization activities. Researchers developed the Geo Math application based on the design created. Furthermore, validation is carried out in this phase to ensure the suitability of the product based on assessments of 5 expert lecturers.

The implementation phase is the trial phase of the Geo Math application that has been developed. In this phase, the researchers evaluate the practicality of the Geo Math applications.

The evaluation phase aimed to assess the quality and effectiveness of the application and the learning process both before and after implementation. Schematically, this development can be described as follows:

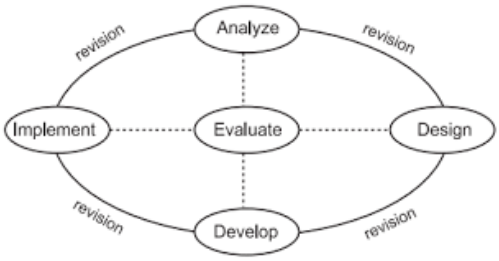

Figure 1. ADDIE model (Branch, 2009)

This study went through 3 trial stages, which included a one-to-one trial, a small group trial, and a field trial. In the one-to-one trial phase, 3 second-year students from a senior high school in Banda Aceh, Indonesia, were selected. They were selected by considering their ability level and the availability of smartphones with the Android operating system. Furthermore, the small group trial involved 11 second-year high school students from Banda Aceh, Indonesia, while the field trial involved 60 second-year high school students. The selection of the subjects was carried out by considering the number of test subjects, as explained by Branch (2009).

2. Data Collection Instruments

The instruments used in this study were media validation sheets and teacher assessment sheets. The instruments consist of media expert and material expert validation sheets to measure the validity of the Geo Math applications. Then, the teacher assessment sheet was used in a small group trial to measure the practicality of the Geo Math application. The instruments used have been validated by expert lecturers in terms of construction and content. Moreover, the data from the pretest and post-test were obtained from students' scores in solving questions within the Geo Math application based on indicators of spatial ability. It aimed to determine the effectiveness of the Geo Math application in learning mathematics, especially geometric transformations.

3. Data Analysis Techniques

Data analysis was carried out to assess the validity and practicality of the Geo Math application and was used as a reference in revising the application if needed. The data was in the form of quantitative data on a Likert scale of 1–5. Then, the data was analyzed by calculating the average score for each aspect of the assessment using the following formula:

$$Average\ score\ (\bar{x}) = \frac{Total\ score\ for\ each\ aspect\ (\sum x)}{number\ of\ indicators\ (n)}$$

The validity and practicality of the application are assessed based on the calculation results at least reaching the good category. The validity and practicality of the application are determined by comparing the results of the data analysis with the following media criteria (Widoyoko, 2016), as presented in Table 1.

Table 1. Learning media quality interval

Interval	Criteria
$\bar{x} > 4.2$	Very Good
$3.4 < \bar{x} \leq 4.2$	Good
$2.6 < \bar{x} \leq 3.4$	Enough
$1.8 < \bar{x} \leq 2.6$	Less
$\bar{x} \leq 1.8$	Very Less

Furthermore, the data obtained at the evaluation stage in the form of student pretest and post-test scores were analyzed using SPSS. The data obtained were subjected to prerequisite tests including normality and homogeneity tests. The t-test was carried out to see the effectiveness of the Geo Math application in learning mathematics, especially geometric transformations.

C. Result and Discussion

The result of this research and development (R&D) is a product in the form of a learning application that integrates the GeoGebra Applet in geometric transformation material. The application was developed based on the ADDIE model which consists of 5 stages, namely analysis, design, development, implementation, and evaluation. The ADDIE model has been instrumental in designing instructional media that effectively meet the objectives of teaching and learning. The model's systematic approach ensures that the needs of students are fulfilled by following the five phases of the structured process.

1. Result

Based on the 5 stages of the ADDIE development model, the following describes the process and results of developing the Geo Math application to determine the validity, practicality, and effectiveness of the application.

a. Analysis

The results of the analysis phase regarding teacher and student perceptions showed that students often face challenges in comprehending geometric transformation material due to several factors. One significant issue is the abstract nature of the subject matter, which can make it difficult for students to grasp and retain the concepts. Additionally, the learning resources and media used to support the learning process are less effective in facilitating an understanding of the concept (Mastura et al., 2022). It means that teachers and students need more innovative learning media to make it easier for students to explore abstract mathematical concepts, especially geometric transformation.

The results of the analysis showed that teachers have used various smartphone-based learning media such as Quipper, YouTube, and Google Classroom applications as seen in Figure 2. Besides, teachers have also used GeoGebra software in mathematics learning. However, learning applications that integrate GeoGebra applets that provide interactive and visual representations of various transformations are still limited. Therefore, in this development research, a Geo Math application that integrates the GeoGebra applet was designed to help students understand transformation geometry material, especially through a dynamic and visual learning approach.

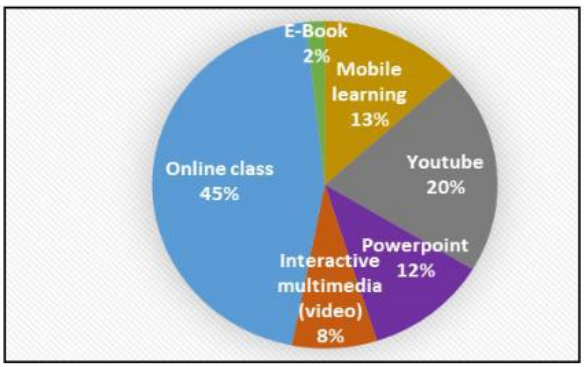

Figure 2. Utilization of technology in learning (Mastura et al., 2022)

b. Design and Development

The Geo Math application consists of several features, namely: (1) a competency page, this page contains core competencies and basic competencies; (2) a concept map containing flow charts related to transformation material; (3) material that includes translation, reflection, rotation, dilation, and transformation composition sub-materials; (4) Exercises, which consists of 10 multiple choice questions created based on spatial ability indicators; and (5) innovator page, containing information about the application such as the name of the innovator, application version, Android version support, application size and advantages of the Geo Math application.

The material contained in this application is presented using the GeoGebra applet. This applet is intended to help students construct an understanding related to various geometric transformation concepts.

Through the GeoGebra Applet, students can explore and observe every transformation that occurs in an object so that they can find a conclusion related to a certain concept. The following displays the GeoGebra reflection applet contained in the Geo Math application, which can be seen in Figure 3.

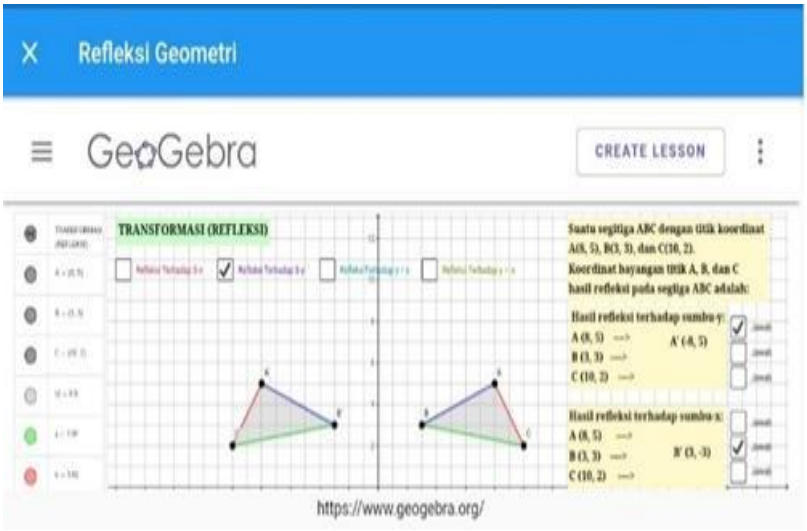

Figure 3. GeoGebra applet display of reflection

The Geo Math application was validated by expert judgment to assess the feasibility of the application and identify areas for improvement. The validation process involved a thorough evaluation by a panel of experts who assessed the application's performance and provided feedback on its strengths and weaknesses. The validity of the Geo Math application was obtained based on the assessment of 5 validators consisting of 3 media experts and 2 material experts. The validation process for the Geo Math application consists of two stages to ensure that it meets the necessary criteria for use.

The results of the assessment by media experts in phase 1 showed that the Geo Math application still needs a lot of revision/ improvement. The three validators provided several suggestions for improvements to the Geo Math application, namely (1) the presentation of content in the Geo Math application was still less attractive; (2) the use of graphics, colors, and

fonts is still inappropriate; (3) it is recommended that the exercise/ quiz menu be made interactive; and (4) the concept map image display must be smoother, sharper with good coloring. The results of the revision based on the media experts' suggestions in the first phase can be seen in Figure 4.

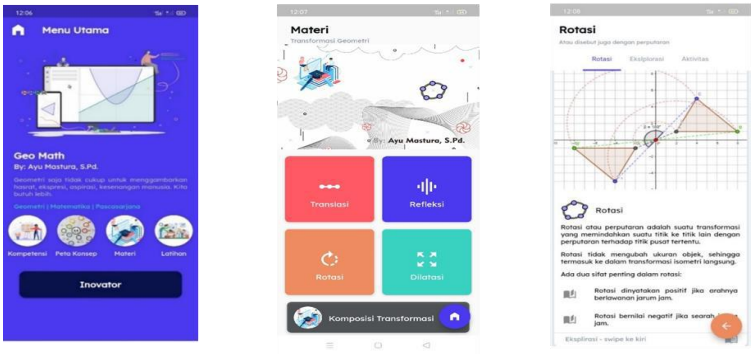

Figure 4. Display of geo math app

Furthermore, the revised application was re-validated by the three media expert validators in phase 2. The following media expert validation results of the Geo Math app can be seen in Table 2.

Table 2. Media expert validation result of geo math app in phase 2

No.	Aspects	Average of Each Aspect
1.	Technical Adequacy	4.2
2.	Content	4.6
3.	Appearance	4.6
	Average	**4.5**

The results of the media experts' assessment of the Geo Math application showed that the average rating score for all aspects is 4.5. Based on the validity criteria of learning media in Table 1, it was found that the application, in terms of the indicators, is in the category of "very valid". In addition, all validators concluded that the Geo Math application could be used without revision. Then, the material expert assessment was carried out by two geometry expert lecturers by providing an assessment sheet consisting of 3 aspects, namely language, content, and application appearance. The results of material expert validation on the Geo Math app can be seen in Table 3.

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Table 3. Material Expert Validation Result of Geo Math App

No.	Aspects	Average of Each Aspect
1.	Language	4.0
2.	Content	4.2
3.	Appearance	4.3
	Average	**4.2**

Based on the table above, the results of the material experts' assessment of Geo Math also showed that the application, in terms of the indicators, is in the category of "very valid". However, the validators indicate that the application still needs minor revisions. There are several comments and suggestions from the media expert validator, namely: (1) there are some typing errors; (2) add materials related to the types of reflection and transformation composition; and (3) adding guidelines to the dilated shapes contained in the GeoGebra Applet. The results of the Geo Math revision based on the suggestions from material experts can be seen in Figures 5 and 6 below.

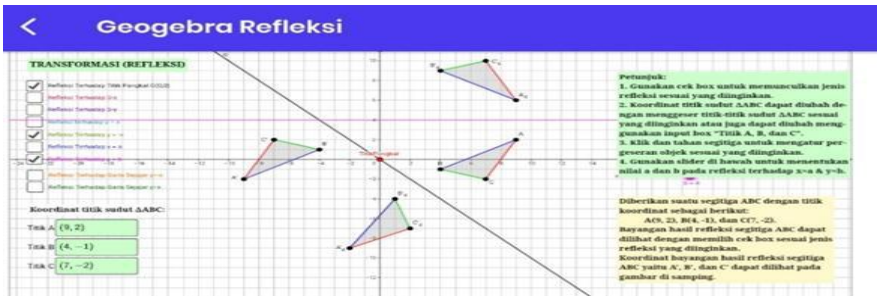

Figure 5. GeoGebra applet view of the reflection

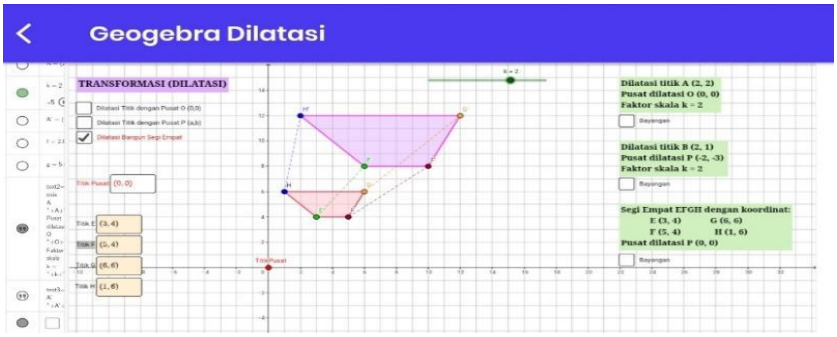

Figure 6. GeoGebra applet view of the dilation

Then, after the Geo Math application was revised based on comments and suggestions from the two material expert validators, the validation process for stage 2 was carried out via Zoom to review the results of the revision of the application. According to the material expert validators, the Geo Math application is good and has been adjusted based on suggestions in stage 1. The results of the validator's assessment stated that the Geo Math application is suitable for use and can be continued with individual trials (one-to-one trials) and small group trials at the implementation stage.

c. Implementation

The data obtained at the implementation stage of the Geo Math application consists of one-to-one trials and small group trials. These trials are part of the testing process to ensure the practicality and usability of the application in mathematics learning, especially geometric transformations. A one-to-one trial was conducted on three 2nd-grade high school students. The results of this trial showed that there were several errors in typing material. This indicates that the application may require further refinement to ensure accurate and reliable data entry. The errors could be due to various factors such as user input mistakes, software bugs, or inconsistencies in the data format.

After the revisions were made, a small group trial was carried out involving 11 2nd-grade high school students. During the testing process, researchers found several problems when using the Geo Math application, there was a display on the main menu of the Geo Math application which was influenced by Android settings in the form of "dark mode". Then, some students also experienced difficulty in determining the coordinates in the GeoGebra Applet because the font size was too small. Therefore, the Geo Math application needs to be revised again before proceeding to the field trial in the evaluation stage. The results of the revisions at this stage can be seen in Figure 7.

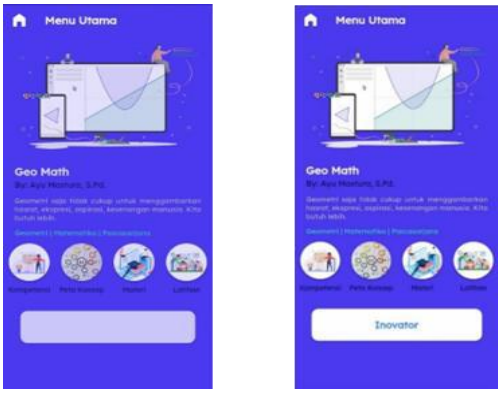

Figure 7. The revision of the geo math (main menu)

Then, data of practicality assessment were obtained by giving teacher assessment sheets to two high school mathematics teachers to assess the quality of the Geo Math application. The data can be seen in Table 4 below.

Table 4. Geo math practicality test results

No.	Aspects	Score	
		Teacher 1	Teacher 2
1.	Language	4.50	4.67
2.	Content	5.00	4.63
3.	Appearance	4.50	4.60
4.	Technical Adequacy	4.13	4.25
	Total Average	**4.53**	**4.54**

The results of the practicality test based on the table above showed that the average rating score by Practitioner 1 is 4.53 and Practitioner 2 is 4.54. Therefore, based on the criteria in Table 1, it can be concluded that the Geo Math application meets the criteria of "very practical". This showed that Geo Math could be used by teachers and students as a learning medium, especially in learning geometry transformation.

d. Evaluation

The results at this evaluation stage were obtained through testing the Geo Math application on high school students, and data were collected from two classes. Field trials were conducted to assess the effectiveness of

the Geo Math application in improving students' mathematical spatial abilities. A pretest-posttest design was used to determine the effectiveness of the Geo Math application. The data of the pretest in this research was the result of students' scores in solving spatial ability questions contained in the Geo Math application. The test was given at the beginning of the meeting before students in the experimental class and control class were taught geometric transformation material.

The data of the post-test in this research was students' scores after using the Geo Math application in the learning process for the experimental class and conventional learning for the control class. Based on the analysis results, the average pre-test score in the experimental class was 37.43, and in the control class 35. From the post-test results, the average score in the experimental class was 80.5 and the control class was 64.2. Based on the results obtained, the average test results of students in the experimental class improved better than those in the control class. After obtaining the results of the students' average scores, data prerequisite tests were carried out, namely the normality test and homogeneity test. The data of the normality test can be seen in Table 5.

Table 5. Test of normality

Class		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pretest	Experiment Class	.081	30	.200*	.981	30	.860
	Control Class	.094	30	.200*	.972	30	.594
Postest	Experiment Class	.095	30	.200*	.975	30	.673
	Control Class	.112	30	.200*	.943	30	.111

Based on the output results in the table above, it can be seen that the sigmoid value is greater than 0.05, so it can be concluded that the variables are normally distributed. Furthermore, a homogeneity test was carried out to determine the variance of the data for both experimental and control classes having the same variance. The data of the homogeneity test can be seen in Table 6 below.

Table 6. Test of homogeneity

		Levene Statistic	df1	df2	Sig.
Result	Based on Mean	1.900	3	116	.133
	Based on Median	1.678	3	116	.176
	Based on the Median and with adjusted df	1.678	3	98.357	.177
	Based on trimmed mean	1.773	3	116	.156

Based on the table above, it is known that the significance value is greater than 0.05, which was the basis for decision-making in the homogeneity test. It can be concluded that the variance of students' pretest and post-test data is the same or homogeneous, in other words, the two classes have homogeneous abilities. Then, a t-test was carried out to see the effectiveness of learning using the Geo Math application. The t-test result can be seen in the Table 7.

Table 7. Paired sample statistic

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	38.27	30	11.064	2.020
	Postest	80.27	30	10.065	1.838

Based on the table of descriptive results, the average score of pretests was 38.27 and the average score of post-tests was 80.27. It can be concluded that the average pretest and post-test scores are 37.10 < 38.95, which means that descriptively there is a difference in the average pretest and post-test. Furthermore, the result of the t-test analysis is presented in Table 8.

Table 8. Paired samples test

	Mean	Std. D	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pretest - Postest	-42.00	14.57	2.660	-47.44	-36.560	-15.78	29	.000

Based on the table above, it is known that the Sig value. (2-tailed) is 0.000 < 0.05, so H_0 is rejected and H_a is accepted. It can be concluded that

there is an average difference between the pretest and posttest results, which means that the implementation of the Geo Math application in mathematics learning, especially in teaching geometric transformation, can be said to be effective. Moreover, from the output above can be seen that the df value is 29 and the t table value based on the distribution of t table statistical values is 2.0452. Thus, the t value is 15,789 > t table 2,045, it can be concluded that H_0 is rejected and H_a is accepted, so it showed that the use of the Geo Math application in mathematics learning, especially in geometric transformation, can be said to be effective.

Moreover, the field trial also involved mathematics teachers as facilitators and researchers themselves as observers who assessed the learning process. The observation results showed that all students could install the Geo Math application without any problems. The majority of students could operate the GeoGebra Applet in the Geo Math application to complete the activities on the worksheet well. However, some students experience difficulty in operating the GeoGebra Applet. This was because the screen sizes of the smartphones were too small, unlike current smartphone standards. Then, some students do not understand the prerequisite material for coordinate systems so that students have difficulty determining the coordinates of an object. In general, learning activities ran well and were by the learning objectives. Students could make general conclusions regarding the concept of transformation of an object based on the results of exploration with the GeoGebra Applet using the Geo Math application.

2. Discussion

The process of Geo Math application development in this study used the ADDIE development model. Based on the results, the Geo Math application has met the validity, practicality, and effectiveness criteria. The application consists of several features, there are menu of competency, concept maps, a material page, a quiz, and about the innovator. The material contained in the application is presented using the GeoGebra Applet. Through the GeoGebra Applet students can explore and observe

every transformation that occurs in an object, so that they can find a conclusion related to a particular concept.

The results showed that the Geo Math application can be used easily and is very helpful for students in understanding and discovering abstract mathematical concepts, especially in geometric transformation. The GeoGebra Applet allows students to directly work with interactive images to analyze and understand mathematical concepts, making the learning process more engaging and efficient. This interactive approach enables students to visualize and manipulate mathematical objects, which can enhance their understanding and retention of the material (Alkhateeb & Al-Duwairi, 2019; Jabaliah et al., 2021).

Moreover, the interactive approach in the Geo Math application, utilizing GeoGebra applets, indeed enhances students' spatial abilities. By allowing students to visualize and manipulate mathematical objects, they can better understand the spatial relationships and properties of geometric transformations. Kim & Irizarry (2021) stated that technology-based learning media can assist students in learning geometry which requires high spatial abilities. Some previous studies have shown that the use of technology in learning such as the GeoGebra application (Sugiarni et al., 2018; Suprapto et al., 2021) and Augmented Reality (AR) applications (Papakostas et al., 2021) can be used to improve students' spatial abilities.

Additionally, the use of GeoGebra applets can help students take ownership of their learning, as they can investigate and explore mathematical concepts independently rather than relying solely on teacher instruction (Ngwabe & Felix, 2020; Schaver, 2019). This is in line with the previous research stated that the use of GeoGebra Applets in learning can help students to be more actively involved in acquiring knowledge and also make it easier for students to analyze and understand abstract objects or those that are difficult to describe manually so that learning becomes more efficient (Wassie & Zergaw, 2019; Radović et al., 2020; Ziatdinov & Valles, 2022).

However, the findings in this research indicate that students experience difficulties in using the Geo Math application due to students lack of a fundamental understanding of the prerequisite material,

particularly the coordinate system. For example, during the learning process using the Geo Math application, it was found that students were having trouble interpreting the coordinate system within the GeoGebra applet. So that, students experience difficulty in solving the problems given. This showed that understanding the prerequisite material, such as the coordinate system, is crucial for effectively using the Geo Math application. This foundational knowledge enables students to better grasp the concepts of geometric transformations.

Research has shown that students who have a strong grasp of prerequisite concepts perform better in subsequent courses (Gafoor & Kurukkan, 2015; Terry et al., 2016). Students who understand prerequisite material can learn new concepts more quickly and efficiently because they don't have to re-learn or re-visit foundational topics. In summary, understanding and building on prerequisite material is essential for students to develop a deep and lasting understanding of mathematical concepts, and it is a critical component of effective educational practices.

Furthermore, by using the Geo Math application in learning mathematics specifically geometric transformation, can help teachers enhance their teaching effectiveness, engage students more effectively, and provide better learning experiences for their students. In line with the research of Kounlaxay et al., (2021), emphasized that by utilizing technology-based learning media, teachers can significantly enhance the learning process by leveraging strategies that foster a high potential for better understanding. This can lead to increased student engagement and motivation, ultimately contributing to improved academic outcomes (Aulia et al., 2024; Wassie & Zergaw, 2019).

The research results of Radović et al., (2020) showed that the use of technology in learning is more effective than conventional learning methods. Moreover, some previous studies found that Android-based learning media significantly improved student achievement in mathematics (Hidayat et al., 2023; Permatasari et al., 2023; Wahid et al., 2020). This can ultimately contribute to improved academic outcomes and better preparedness for future educational and professional pursuits. The positive

results from using digital media in education, such as the Geo Math application, could significantly influence policymakers to adopt similar tools on a broader scale. This would help equip learners with essential 21st-century skills, such as digital literacy, problem-solving, and critical thinking. By adopting digital tools like Geo Math and fostering a balanced approach to social media use, educators, parents, and policymakers can empower students to become responsible digital citizens, equipped to thrive in an increasingly interconnected and digitalized world.

This research and development of The Geo Math application is expected will help teachers and students create a more interactive learning environment that can support students to be actively involved in learning. However, due to the author's limitations, this research is only limited to geometric transformation material. Future researchers can continue this research and development by developing GeoGebra Applets related to various transformation compositions more widely. Besides that, it is recommended that future researchers who want to develop mathematics learning applications develop other geometry materials such as plane shapes, space shapes, or three-dimensional materials so that the mathematics learning applications, especially geometry material, are more comprehensive. Furthermore, the evaluation carried out in this research is still on a small scale. To further advance the research, it is recommended that the evaluation stage be continued with broader research subjects for a more comprehensive understanding of the findings and their applicability to a wider range of scenarios.

D. Conclusion

Based on the results and discussion, it can be concluded that the Geo Math application is both practical and effective for use in learning geometry. Its interactive and visual approach, facilitated by GeoGebra applets, has proven to enhance students' understanding and engagement with geometric transformations which can help improve students' spatial abilities. By engaging with mathematical concepts through interactive tools, students can develop a deeper understanding of the relationships between different elements and

enhance their capacity to think spatially. This makes the application a valuable tool for creating a more interactive and effective learning environment in learning mathematics, specifically geometric transformation. Additionally, the results indicate that students who used the application performed better in learning assessments, suggesting that it can be an effective supplement to traditional teaching methods. Geo Math application can also be used as a source of student learning independently anywhere and anytime.

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