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Interactive Learning Media With Augmented Reality (AR) Geogebra for Teaching Geometry in Elementary School

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Abstract

In Semarang's elementary maths education, augmented reality (AR) and three-dimensional tech are underused in geometry instruction. These technologies promise an engaging and interactive presentation of three-dimensional objects. Presently, educators are confined to traditional tools like PowerPoint, providing a less immersive learning experience. This study addresses this gap with AR Geogebra, a tailored interactive tool for geometry instruction. Developed using the ADDIE model, the study involved fifty fifth-semester university students. Notably, material and media validation scored 90%, deeming it "extremely valid." Practicability, assessed by the experimental class and subject teacher, reached 90%, indicating high practicability. Post-test results showed an N-gain of 0.39 for the exposed group, surpassing the control group's 0.02. In conclusion, AR Geogebra proves an effective pedagogical approach for geometry instruction in elementary maths education.

INTRODUCTION

Background of The Study

The widespread effects of the COVID-19 pandemic have impacted the lives of the Indonesian people, extending beyond isolated areas to reach a larger population. The education system of Indonesia quickly implemented home-based learning to address the gap. Therefore, geometry courses for the odd semester of 2021/2022 had to be conducted exclusively online. Google Classroom became the preferred platform. In response to government directives and public health guidelines, institutions

must implement online learning for all individuals to ensure compliance with home quarantine and minimize physical interactions (Khasanah et al., 2020). Geometry was taught through in-person interactions between the teacher and students before the COVID pandemic. COVID-19 is the one positive aspect in this situation. Educators were compelled to adapt to virtual instruction and utilize technology efficiently due to the digital technologies provided to them. This transition necessitates a consistent innovation of our faculty and students, as well as the conversion of traditional educational practices to modern ones, specifically in the context of transforming geometry (Dinata, 2019).

Online learning has become common, with classes accessible through internet-based applications that incorporate PowerPoint slides, e-books, animated videos, and both individual and group assignments (Abduin, et al., 2020). The shift from traditional classroom interactions to online labs requires educators to integrate technology in an innovative manner. Online learning tools such as Zoom, Google Classroom, and Video Conferences have effectively facilitated communication between teachers and students, as noted by Jamaluddin et al. (2020).

Designing an engaging, lively, and captivating virtual class is indeed a highly complex endeavor. The obstacles include a lack of workforce, inadequate infrastructure access, and technological challenges. Long-lasting partnerships involving all stakeholders in education are not only ideal but essential, although the approach to overcoming these challenges may differ. Training teachers and instructors to enhance their abilities and skills is a pressing investment, according to Wahyono et al. (2020).

Problem of The Study

In reaction to the Work From Home (WFH) directive issued by the Indonesian government, academic establishments have uniformly implemented online learning platforms. Instructors and lecturers are often obliged to conduct classes remotely from their residences. Conventional classroom lesson plans are automatically converted to online formats, requiring adjustments to accommodate the requirements and limitations of the digital learning environment (Dinata, 2019). Syllabi and lesson plans must be synchronized and modified by both instructors and learners to accommodate the distinct requirements of online education. In an effort to combat the monotony and disengagement that are prevalent in online learning, instructors are now required to imbue their use of interactive and user-friendly media with humor. It is imperative that the educational tools and media utilized not only enhance the learning process but also foster student motivation and have a positive psychological impact (Nur, 2016).

Based on interviews conducted at the Department of Primary Teacher Education, University of PGRI Semarang, it was discovered that a significant proportion of instructors primarily utilize PowerPoint as the medium for instruction, which is also disseminated via online platforms including Google Classroom. Nevertheless, this approach is not without its constraints, given that the PowerPoint resources frequently comprise solely essential details and do not delve into comprehensive analyses. Additionally, students' reluctance to ask questions is hampered by the absence of discussion sessions during online learning. Students in their fifth semester subsequently stated in an interview that they required a variety of media in order to comprehend the complex concepts of geometry. Regrettably, they solely received PowerPoint presentations pertaining to transformations, lacking a more profound comprehension of the geometric formulations that underpin them. The urgency for instructors to develop a more meaningful mathematics learning model is acknowledged by the instructors. Furthermore, their objective is to develop proficiency in utilizing mathematics software that is both intuitive and functional (Noornia et al., 2015).

Research's State of The Art

The researcher concludes that lecturers are not fully maximizing their utilization of media during online learning based on observations and interviews. Lecturers frequently transcribe content from textbooks to PowerPoint presentations and present them to students without engaging in additional discussion. Consequently, students find it challenging to comprehend the material, leading to a detrimental effect on their academic performance. Students' lack of readiness for online learning and the absence of interactive discussions during one-way content delivery are two key factors contributing to their poor understanding. This is a crucial matter, and potential educators should thoroughly evaluate technological advancements in education. Geogebra is considered one of the top educational tools for teaching geometry, particularly in its augmented reality (AR) format. AR Geogebra is an effective tool for teaching mathematics as it allows for the demonstration and visualization of mathematical concepts, aiding students in constructing and enhancing their mathematical comprehension. Murtianto and Harun (2014) argue that student-centered teaching-learning processes should prioritize creativity, logical ability, contextuality, and offer challenging and enjoyable learning experiences through hands-on activities. Geogebra is compatible with this method and is perfect for enhancing creativity and logical reasoning abilities when studying transformation geometry. Fitriani et al. (2019) highlight that the Geogebra software enables teachers to generate graphical representations and geometric explanations, enhancing students' comprehension of mathematical concepts. Geogebra provides teachers with various teaching and learning options that enhance student learning outcomes. Geogebra is tailored for educational purposes, motivating students to participate in experimental procedures by solving problems, which helps them uncover mathematical concepts. AR Geogebra tackles challenges by enabling the straightforward and accurate creation of geometric objects (Nur'aini et al., 2017).

Gap Study & Objective

Based on the background, the objective of this study is to develop and make interactive learning media of Geogebra for teaching learning Geometry. There are many media used in learning geometry in the classroom, but there are still few elementary school teachers who use renewable technology, this is because teachers are still weak in developing new media such as augmented reality which is able to display three-dimensional objects and is attractive to teachers. and students, the innovation carried out is packaging geometry learning media that is adapted to children's learning styles with the help of GeoGebra AR-based learning media.

METHOD

Type and Design

The methodology utilized in this study is Research and Development (R&D). Mandailina et al. (2019) define R&D as a procedure encompassing the development of a new product, enhancement of pre-existing ones, and assessment of their effectiveness. R&D, according to Kurniawati and Negara (2019), involves conducting research in order to create products that meet specific requirements. Dwiranata et al. (2019) highlight R&D as a procedure for developing new products and improving existing ones while assessing their efficacy. This research endeavors to develop virtual learning materials, more specifically Geogebra, for the purpose of instructing Geometry in an online learning environment, utilizing R&D as its research methodology. Five phases comprise the development model: evaluation, design, development, and implementation. In order to assess the effects of

integrating AR Geogebra virtual learning materials into an online geometry education setting, this research utilizes a Nonequivalent Control Group configuration.

Data and Data Sources

This research has a control group but cannot function fully to control independent variables which affect the implementation of the experiment (Sugiyono, 2015). This research was divided into two groups, and each group used a different learning system. In the experiment class, interactive virtual learning of AR Geogebra was applied and at the same time, a conventional learning system was applied in the control class. Samples of this study were consisting of a class of 3A as the experiment class and a class of 3B as the control class. The class setting was arranged to contain students with relatively the same ability. Consequently, a full sample of the population was 33 students. This study applied some instruments they were material validity sheet, media validity sheet, students' responses sheet, lecturers' responses sheet, and test of students' learning results.

Data Collection Technique

This study applied some instruments they were material validity sheet, media validity sheet, students' responses sheet, lecturers' responses sheet, and test of students' learning results. The instrument grid or validity indicator uses a Likert scale, while the test used is in the form of essay questions which are able to holistically measure students' cognitive abilities.

Data Analysis

Analyzing the data of validity, data of questionnaire on responses, first data, and final data until drawing a conclusion whether the result of learning by using learning media of Geogebra is better or not based on the comparison of N-Gain score of each class. The Normality-Gain Test is a test that can provide a general picture of the increase in learning outcome scores between before and after the implementation of the treatment. The N-Gain test formula is:

$$N - Gain(g) = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

Meanwhile, for the book category, you can use the interpretation of the Normalized-Gain index (g) according to Hake which has been modified:

Table 1. N-Gain index interpretation table

N-Gain Skor (g)	**Interpretation**
$-1{,}0 < g < 0{,}0$	Less
$g = 0$	fixed
$0{,}0 < g < 0{,}3$	low
$0{,}3 < g < 0{,}7$	medium
$0{,}7 < g < 1{,}0$	high

RESULTS

Analysis

This study analyzed the needs of students of 3rd semester Class in learning Geometry. They expressed that space geometry is difficult to understand, mainly specific materials such as volum geometry Therefore, it is necessary to design a learning media comprising a syllabus, lesson plan, and learning media which can increase students' ability to understand the subject of geometry.

Design

As an aforementioned explanation, the learning media to be developed in research are three types, they are (1) syllabus, (2) lesson plan, and (3) learning media namely AR Geogebra as the interactive virtual learning media for teaching and learning Geometry. The process of developing the learning media consists of the first draft. The first draft was validated by two competent experts in material and 2 competent experts in media to assess the eligibility of learning media/learning application. Afterward, do some revisions based on the comments and suggestions from the validators. In the end, the final draft. Learning media in the final draft was also tested. The discussion of media development for each media can be explained as follows:

Syllabus

The syllabus development is the first and basic to get the objectives of learning achieved suitable with the learning process as written in the process standard Kemendikbud (2016), consisting of planning, implementing, and evaluating/assessing. The discussion in this study is limited to planning and implementing the learning process. The learning plan in this study consists of a syllabus and lesson plan. Validator stated that the syllabus was good and can be used for minor revision. Some values must be added to the syllabus namely humanity, teamwork/cooperation, respect, and responsibility. Moreover, the validator suggested that instrument of assessment must contain objectives and competence to achieve.

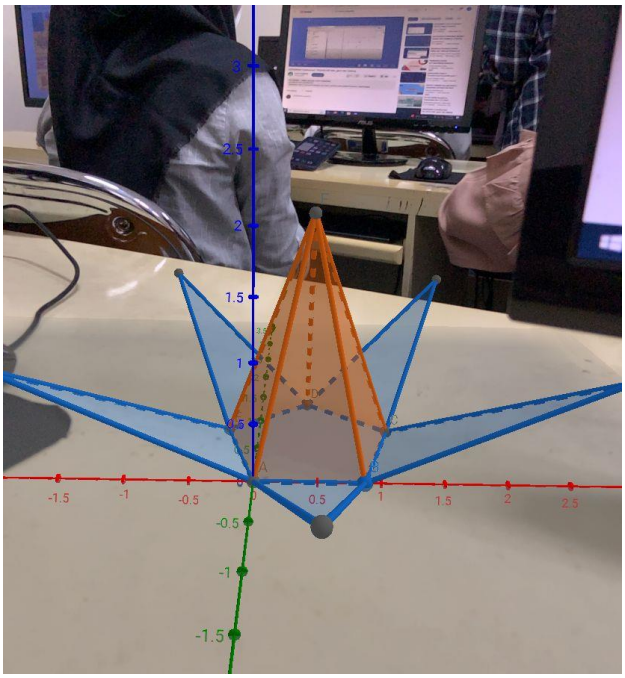

Figure 1. Interactive learning media of AR Geogebra for teaching geometry

Lesson plan

Arranging the lesson plan is part of the learning plan. It is the same with the syllabus where the validator stated that the lesson plan was good and has adapted and adjusted to the condition of the school. In addition, the lesson plan has adapted and adjusted the online class system.

Virtual Interactive Learning Media

Learning media of AR Geogebra for teaching geometry in online learning. Generally, the validator said that Virtual Learning Media of AR Geogebra for teaching learning geometry can be used by minor revision and adjusting to lesson plans with an online learning class system. In the Figure 1. indicate interactive learning media of AR Geogebra for teaching geometry.

Development

The development of the product of interactive learning media of AR Geogebra is carried out right after the learning media (syllabus, lesson plan, and interactive learning media of AR Geogebra for teaching material of geometry for online learning) is revised following the suggestion and comments from the validator. Subsequently, a trial test in the field was conducted to obtain inputs and suggestions to revise and complete the learning media itself. In the Figure 2. shows that developing the interactive online media which is supported by the Geogebra application to teach the subject of the linear program can increase students' skills in mathematics literacy.

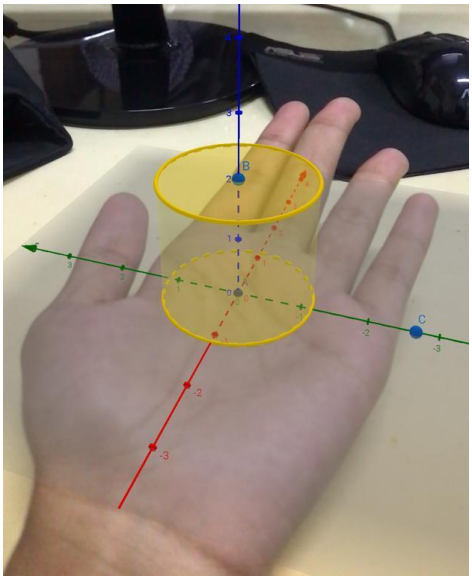

Figure 2. Interactive learning media of Geogebra to teach Geometry

The research at school was conducted on September 7 – October 7, 2022. The aim is to know how successfully the product of researchers is being used. The researcher has 2 methods for collecting the data namely a questionnaire and a test. A product test was carried out on September 17, 2022, to know the rate of media practicality. Here below is an analysis of data from a questionnaire of teachers' and students' responses after the trial product was being tested. Learning media by using the software Geogebra from the teachers' responses was rated 90% and the result of analysis from the data of students' responses on the learning implementation followed by 26 students in the phase of the limited trial revealed 91%. From all aspects asked, the average percentage of students' responses was 90,86%. The conclusion is a high percentage of students in giving positive responses proving that interactive virtual learning media of AR Geogebra is considered effective and the test proved.

On September 19, 2022 – October 7, 2022, the product of learning media was used in the experiment class. Meanwhile, the control class applied conventional learning. The test was administered to compare whether the learning result by applying learning media is better than by applying conventional class. There are two kinds of tests namely pre-test and post-test. Each sample was treated for 2 meetings for both experiment and class control. A quantitative comparative quasi-experimental design was used in this study. Comparative research is research by comparing an existence of a variable or more which is given to two different samples or the same sample at different times (Sugiyono, 2015). To determine the effect of learning media effectiveness of AR Geogebra to teach Geometry in an online learning system, this study used a Non-equivalent control group design. This design has a control group but it doesn't function fully to control independent variable that affects the implementation of the experiment (Sugiyono, 2015).

Implementation

Before the two meetings were treated, each class was given a pre-test which is validated by the same question items between the control class and the experiment class. Moreover, the researcher did an analysis of normality and homogeneity on the pre-test value of each class. For the normality test, this study used Lilliefors-test with a significant rate of 5%. The criterion for the normality test for the normally distributed sample is $L_{count} \leq L_{table.}$ In the control class, it was 0,13. For n=16 with a significant rate, a 5% value of L_{table} Based on the table of critic value of Lilliefors-test was 0,13. It shows that $L_{count} \leq L_{tabel}$ namely 0,13≤0,20 so H_0 is accepted. It concludes that the control class comes from a population with normal distribution. In the experiment class was 0,17. For N=17 with a significant rate as 5% value L_{table} based on the table of critic value of Lilliefors test was 0,1699. It showed that $L_{count} \leq L_{table}$ namely 0,17≤0,20, so H_0 was accepted. It concludes that the experiment class consists of a population with normal distribution.

Moreover, for the homogeneity test, the researcher used the Bartlett test with a significant rate of 5%. The criterion used in the homogeneity test from the sample with the same variants is $b_{count} \geq b_{table}$. In the control class and experiment class was 1,39 and b_{tabel}=0,88. For n_1=16 and n_2=17 and k = 2 with a significant rate of 5%. It showed that $b_{count} \geq b_{table}$, so H_0 was accepted. The conclusion is that the control class and experiment class have the same variants from post test.

Furthermore, media was being trial tested in experiment class by 2 meetings. The discussion of trial in the experiment class is explained as follows:

After 2 meetings of learning conducted to know whether the learning process by using media in class 3A is better or not than conventional learning done in class 3B, the researcher administer the validated post-test with the same question items from both the experiment class and control class. Then, analyzing the final data namely analyzing the normality and homogeneity on the score of the post-test of each class. For the normality test of final data, this study used the Lillifors test with a significant rate of 5%. The criterion in the normality test for the sample with normal distribution was $L_{count} \leq L_{table.}$ The control class was 0,11. For n=16 with a significant rate of 5% where the value L_{table} based on the table of critic value of Lilliefors test is 0,12. It showed that $L_{count} \leq L_{table}$ namely 0,11≤0,20, so H_0 was accepted. It concludes that the control class comes from a population with normal distribution. Moreover, for experiment class was 0,0999. Where for n=17 with a significant rate of 5% value L_{table} based on the table of critic value of Lilliefors test is 0,09. It showed that $L_{count} \leq L_{table}$ namely 0,09 ≤ 0,20, so H_0 was accepted. It implies that the experiment class came from the population with normal distribution.

Meanwhile, for the homogeneity test on final data, the Bartlett test was used with a significant rate of 5%. The criterion in the homogeneity test for the sample with the same variants was $b_{count} \geq b_{table}$. In the control class and experiment class was 1,34 and b_{table}=0,88. Where n_1=16 and n_2=17 and k

= 2 with a significant rate of 5%. It showed that $b_{count} \geq b_{table}$, so H_0 was accepted. It implies that the control class and experiment class have similar variants with post test. In the Figure 3. indicate discovered that the development of interactive mathematics learning media of online class flow which is supported by Geogebra to teach integral of the area can increase interactive learning.

Figure 3. AR GeoGebra-Based interactive learning media

The result of this study is strengthened by Asryana et al (2017), who showed that developing AR Geogebra as interactive learning media can increase students' ability in spatial. Moreover, Mimbadri et al (2019), discovered that the development of interactive mathematics learning media of online class flow which is supported by Geogebra to teach integral of the area can increase the result of students learning. Supriadi (2015) focuses much more on teaching geometry by utilizing Geogebra. He concluded that it can elevate the students' mathematical communication for 80 percent of Islamic Secondary School students (Madrasah Tsanawiyah). Other research by Fatoni et al (2017), revealed that developing online interactive learning by using the software Geogebra to teach quadratic equation make students more enthusiastic and energetic to study holistically. Zarkasyi (2015), in his study also discovered that the development of learning media for AR Geogebra can increase the student's ability to visualize to learn integral.

Evaluation

After obtaining the value of those two classes, the result shows that the average score of n-gain for the experiment class is 0,39 or 39% and it is rated as ineffective. Meanwhile, the result for the average score of n-gain for the control class is 0,02 or 2% and it is considered ineffective. The conclusion is that the use of learning media of AR Geogebra during the teaching-learning process is

ineffective to increase the result of students learning in learning AR Geogebra, especially for students in class 3rd semester Primary Teacher Education Universitas PGRI Semarang academic year 2022/2023.

In the meantime, the use of conventional learning methods is also ineffective to increase students learning resulting in learning Geogebra of students class in class 3rd semester Primary Teacher Education Universitas PGRI Semarang academic year 2022/2023 (Shafa & Yunianta, 2022). Their study shows that developing the interactive learning video which is supported by the Geogebra application to teach the subject of the linear program can increase students' skills in mathematics literacy. Moreover, Albano & Dello Iacono (2019) revealed that learning by using Geogebra is positively making the students' learning atmosphere getting better and more convenient. Osypova & Tatochenko (2021) emphasized that, in the future, all teachers must utilize the application Geogebra to support teaching learning in the classroom because this software effectively helps everyone to understand mathematics, mainly to understand Geometry much easier. In addition, Wassie & Zergaw (2019) explained that by using Geogebra, students can travel via virtual geometry joyfully, and their ability in spatial getting better. Strengthened by Firmansyah et al (2020) which shows that using Interactive Learning Multimedia for Mathematics Subjects for Grade 5 Elementary Schools can improve results, student learning increases by 50 percent, then Tuzzahro et al (2021) also explained that by developing Augmented Reality-Based Augmented Reality Math Comic Learning Media on Spatial Volume Material it can improve students' spatial abilities to be better, then Rusnandi et al (2016), showed that implementing augmented reality (AR) in the development of 3D spatial modeling learning media for elementary school students was able to increase student motivation. In the Figure 4. students create learning media for transformation geometry courses assisted by AR GeoGebra.

Figure 4. Location of research evaluation at Universitas PGRI Semarang

DISCUSSIONS

In this research, it is the result of observations during one semester in the mathematics education study program at Universitas PGRI Semarang in 2023. Students are required to create learning media for transformation geometry courses assisted by AR GeoGebra, from 8 materials in the

transformation geometry course, students are actually guided by researchers. so that they master the material of transformation geometry well and holistically, in conducting this research using the ADDIE model, in the analysis stage it has been carried out by analyzing the learning situation in class related to the course of transformation geometry, there is a lot of input from mathematics students at PGRI Semarang University who hope for innovation in learning in classes where lecturers have only explained using a compass and ruler, there has been no renewable technology used, lecturers have not used augmented reality-based learning media, so innovation is needed in learning transformation geometry. The design stage has been carried out with the process of creating a product design for transformation geometry learning media based on AR GeoGebra which is packaged attractively according to the learning style of students in the mathematics education study program at PGRI University Semarang. The learning media design has been created attractively with 8 chapters packaged using AR Geogebra in each material. so that augmented reality in the form of three-dimensional objects can be seen by users of transformation geometry learning media. Then, at the development stage, 8 chapters of transformational geometry learning media products were developed which were packaged attractively based on AR GeoGebra, then validated by material experts and learning media experts with excellent results and suitable for use in the classroom learning process.

Next, the implementation stage was carried out, in the implementation stage the learning media product for the GeoGebra AR-based transformation geometry course was tested for one semester in the mathematics education study program at PGRI University Semarang, where students actually used eight chapters of learning media which were packaged in an interesting and fun way for students. , students are required to install the AR GeoGebra application on their respective smartphones and the results are that they are very enthusiastic about participating in transformational geometry learning from the beginning of the semester to the end of the semester, the final stage is the evaluation stage which shows that based on the pretest and posttest results related to the material on transformational geometry and the final results are seen from the mid-semester exam scores and final semester scores processed using the t test and N Gain test which shows that students who use GeoGebra AR-based learning media get very good grades and are able to improve student learning outcomes.

This study concludes that the development of AR Geogebra as virtual learning media to teach geometry for online learning by using the development model of ADDIE (analysis, design, development, implementation, evaluation) is considered practical. The researchers have conducted 5 phases to apply ADDIE, they are; in the phase of analysis, the suitable and relevant needs of media to teach geometry is Geogebra. In the phase of design, the selected media is designed to adjust to the needs of students in learning transformation geometry namely by designing learning media of Geogebra to teach translations, reflection, rotation, and dilatation. In the phase of development, the media made is validated by the experts. There were 2 experts on material and 2 experts on media. They evaluate and assess whether the media is eligible or not to use. The final phase is evaluation. In this phase, the product is evaluated after being trial tested. The rate of valid the virtual learning media of Geogebra for teaching transformation geometry in online learning is rated valid based on the validity given by experts of material as 91% and based on the expert of media as 89,5%. The effectiveness of virtual learning media of AR Geogebra for teaching transformation geometry in online learning is considered ineffective from the viewpoint of comparison of the average score of n-gain between the experiment class and control class. In the experiment class, the average score of n-gain is 0,39 or 39%, meanwhile in the control class is 0,02 or 2%. Despite it being rated ineffective, the comparison of the n-gan score for the experiment class is higher than the control class. It implies that learning by using AR Geogebra in teaching geometry is perceived as effective. The rate of media practicality of virtual learning media AR Geogebra in learning geometry via online learning based on the result of teachers'

questionnaire is 4,5 or 90% and the result of students' questionnaire has a higher percentage namely more than 90%. The conclusion is the learning media of AR Geogebra has a high rate of practicality.

This is in accordance with previous research that links augmented reality to classroom learning, augmented Reality media of AR Geogebra for online learning is effectively used for learning because the average result of the experiment class is better than the control class based on the average value of n-gain in the experiment class being higher than the average value of n-gain in the control class. It implies that learning by using the result of development on Geogebra to teach transformation geometry within online learning is rated effective. This finding is in line with the previous study conducted by Tatarczak & Mędrek (2017) who discovered that Geogebra used in learning online makes students easier to use and understand the spatial in that software. Moreover, a study by Kramarenko et al (2022) showed that digital technology development drives teachers to utilize them as supporting media in teaching mathematics. Dockendorff & Solar (2018), in their study showed that technology integration of AR Geogebra in learning can increase students' motivation because they easily understand three dimension model. Suryani et al (2020), explained that teaching-learning geometry by using AR Geogebra can help students to understand the material delivered by the teacher.

CONCLUSION

The researchers created an augmented reality educational tool for exploring transformation geometry that is both captivating and pleasurable. Universitas PGRI Semarang and other institutions utilize fundamental educational tools such as PowerPoint and Canva for teaching transformation geometry. Augmented reality-based transformational geometry learning media can enhance student motivation and learning outcomes by engaging them in a three-dimensional augmented reality environment. The research is constrained by the absence of student smartphones compatible with GeoGebra AR. Smartphones or tablets that are compatible with Augmented Reality are necessary for thorough research. Expand testing to partner campuses in Semarang and surrounding areas to verify the effectiveness of the Augmented Reality-based Transformation Geometry Learning Media for mathematics education students. The research results are suitable for incorporation into augmented reality learning tools for transformational geometry courses at universities offering mathematics education programs. The product was positively received by students at PGRI Semarang University and can serve as a supplementary learning tool at partner campuses with comparable programs.

SUGGESTIONS

Drawing from the results of their research on third-semester Primary Teacher Education students at Universitas PGRI Semarang, the investigators offer multiple recommendations to be taken into account during the educational process: Due to scientific proof, educators are urged to integrate AR Geogebra's virtual learning resources into their geometry lessons. Both online and offline environments can benefit from the use of this learning tool, especially when internet access is restricted or when COVID-19 is less of a threat and in-person instruction gradually returns. To encourage students' motivation and interest in learning geometry, it is advised that future development of AR Geogebra's virtual learning materials for online instruction include improvements to the teaching of reflection.

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