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Media Pembelajaran Augmented Reality untuk Meningkatkan Kemampuan Spasial Matematis pada Konsep Geometri

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Abstrak

Artikel ini bertujuan untuk mengembangkan media pembelajaran *augmented reality (AR)* untuk meningkatkan kemampuan spasial matematis sekolah menengah pertama pada materi geometri. Metode yang digunakan dalam penelitian ini adalah metode penelitian dan pengembangan dengan mengikuti langkah-langkah pengembangan level 3. Dalam penelitian ini produk yang dikembangkan adalah media pembelajaran *augmented reality.* Teknik pengumpulan data dengan wawancara tidak terstruktur, angket dan test dengan sumber informasi dosen pendidikan matematika, dua orang guru SMP sebagai validator materi dan dosen teknik informatika sebagai validator media. Teknik analisis data dalam penelitian ini menggunakan analisis kualitatif deskriptif. Instrumen penelitian ini menggunakan angket hasil pembelajaran, test hasil belajar geometri, dan dokumentasi. Hasil penelitian menunjukkan bahwa pengembangan *augmented reality* sebagai media pembelajaran dapat digunakan untuk memberikan pengaruh positif terhadap keefektifan pelajaran di kelas. Namun disisi lain kelemahan media augmented reality adalah siswa harus menggunakan perangkat minimal *smartphone* berbasis android dan memiliki kamera di dalamnya. Hasil penelitian yang didapatkan adalah menghasilkan media pembelajaran AR yang mampu meningkatkan kemampuan spasial matematis.

Kata Kunci: *augmented reality*, geometri virtual, kemampuan spasial matematis, pengembangan media pembelajaran

The Augmented Reality Learning Media to Improve Mathematical Spatial Ability in Geometry Concept

Abstract

This study aims to develop an augmented reality (AR) learning media to improve the mathematical spatial ability of junior high school in geometry material. The method used in this study is a research and development method by following the steps of level 3 development. In this study, the product developed was augmented reality learning media. Data collection techniques are unstructured interviews, questionnaires and tests with information sources from mathematics education lecturers, two junior high school teachers as material validators and informatics engineering lecturers as media validators. The data analysis technique in this study used descriptive qualitative analysis. The research instrument used a learning outcomes questionnaire, geometry learning outcomes test, and documentation. The results showed that the development of augmented reality as a learning medium can be used to have a positive influence on the effectiveness of lessons in the classroom. But on the other hand, the weakness of augmented reality media is that students must use a minimum Android-based smartphone device and have a camera in it. The study results obtained are to produce AR learning media that can improve mathematical spatial abilities.

Keywords*: augmented reality; development learning media; mathematical spatial ability; virtual geometry*

INTRODUCTION

There are many different forms of learning media that have been produced with the assistance of computers, one of which is an Android-based application that can be used as a learning media on smartphones. Learning media is a tool that can be used to stimulate student learning during the course of a student's academic career (Coimbra, Cardoso, & Mateus, 2017). An Augmented Reality application is a learning application that integrates 2D or 3D virtual objects into a real-world environment and then projects these virtual shapes in real time to the user (Suzanna & Gaol, 2021). Augmented Reality works with a variety of technologies, including display systems that are useful for combining the real world and the virtual world, sensing and registration functions that allow graphics to be rendered in the proper perspective, and interaction techniques that allow for object manipulation through interface control (Yingprayoon, 2015). The application of Augmented Reality in mathematics education is found in the material of creating space. It is difficult to visualize the shape of the students' spatial structure when studying their spatial structure, thus the teacher must supply the appropriate medium to aid in the learning process. Every mathematical concept can be properly grasped if it is presented in a concrete form, according to Freitas and Campos (2018). Learning medium is required to present the mathematical concept in a concrete manner, according to Dienes. Geometric things can be perceived as real through the use of Augmented Reality technology and Android smartphones. This is accomplished by 3D virtual modeling that is comparable to the real object and can be seen virtually right on the image on paper.

Visual spatial ability is the capacity to accurately perceive and distinguish shapes that are related to space. In mathematics, and particularly in geometry, spatial visualizations are essential. Spatial-visual intelligence, as defined by Thamrongrat (2021), can be characterized as the ability to see the world accurately and to change those perceptions. In mathematics, and particularly in geometry, spatial visualizations are essential. While Nasrudin et al. (2021) describes Visual Spatial Intelligence as an intrinsic intelligence present at birth, intelligence can be educated so that the word "geometry visualization ability" emerges in the trained geometry visualization intelligence, as explained by Howard Gardner According to Hass, visual-spatial intelligence is comprised of four traits, which are imagination, the use of concepts, problem solving, and the search for patterns. The properties of imagination are associated with the activity of envisioning an object and forming visual images in the context of conveying information. Constructing a conceptual framework is an activity that has qualities that are related to the activities of gathering and compiling concepts (Auliya & Munasiah, 2020). These characteristics of problem solving are associated with the capacity to select the most appropriate strategy for solving the challenge. It is related to the activity of discovering patterns in order to solve an issue that is related to geographical problems that the pattern search features are associated to.

Mathematics of flat shapes for junior high school students is a learning material in which students learn about various geometrical features such as planes and vertices and edges; as well as diagonals; space diagonals; and mathematical formulae such as circumference; surface area; and volume (Robert, 2020). Because students' understanding of the visual characteristics and the characteristics of a spatial shape is still weak, it is possible that they will have low levels of conceptual mastery if they rely solely on their imagination. The reason for this is that the learning process provided by the teacher has not yet reached the required level of quality and prerequisite skills. Students must take responsibility for their own learning when learning geometry (Wahyudi & Arwansyah, 2019).

A study conducted with mathematics teachers at Junior High School of 2 Pamarican, West Java, Indonesia revealed that many students continue to have difficulty learning the geometry material of flat-sided shapes and curved-sided shapes. This is due to the lack of visual representations for geometric shapes and limited learning media to describe the characteristics of a shape, and not all students have the same learning experience as their peers. The foregoing explanation inspires researchers to develop the Augmented Reality (AR) Learning Media to Improve Junior High School Mathematical Spatial Ability in Geometry concepts.

METHOD

Using research and development methodologies, and a research and development design that is intended to generate new products in accordance with the level 3 development processes, this study will develop new products (Creswell, 2014). It was discovered that augmented reality learning material may be generated in this study. The processes involved in level 3 development research are divided into seven stages, which are as follows: 1) research on existing products; 2) literature study; 3) product development planning; 4) internal design testing; 5) design revision; 6) product development; and 7) limited trial (Mills, 2012).

Participants in this study were students of Junior High School of 2 Pamarican, West Java, Indonesia were tested both before and after the study. Unstructured interviews, questionnaires, and exams were used to collect data, with information sources coming from mathematics education lecturers, two junior high school teachers who served as material validators, and informatics engineering academics who served as media validators, among others. The descriptive qualitative analysis technique was used in this study to collect and analyze data.

RESULT AND DISCUSSIONS

The results of this study consist of product development planning, internal validation stage, design revision stage, development product stage, and limited trial. The details of this information are as follows.

Product Development Planning

The results of existing product research, literature studies, and field investigations will be used to build Virtual Geometry Learning Media products, which will subsequently be implemented. Prior to creating product designs, it is necessary to analyze existing Augmented Reality learning material, conceptual models that have been produced in the development framework, as well as proposals derived from field research. A draft model was created by the researcher as a result of this information. The draft model is subjected to a critical evaluation on the grounds of validity, practicality, and efficacy, among other things (Pujiastuti, Haryadi, & Arifin, 2020). The findings of a critical review of the existing draft model are used to refine the model, which is then utilized to refine the model. Here is an example Partial design of Virtual Geometry detailed in Figure 1 and Figure 2.

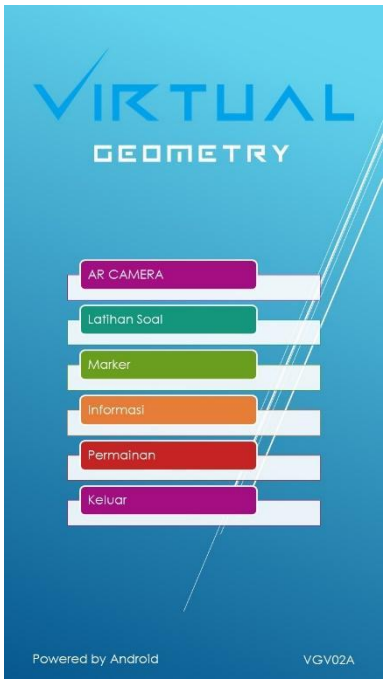

Figure 1. The Main Menu of Virtual Geometry

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The main menu of Virtual Geometry which contains AR Camera menu, Practice Questions, Markers, Information, Games, and Exit menu. Whereas, the scene of Cube Flat Side Room with a View Create a menu captured in Figure 2.

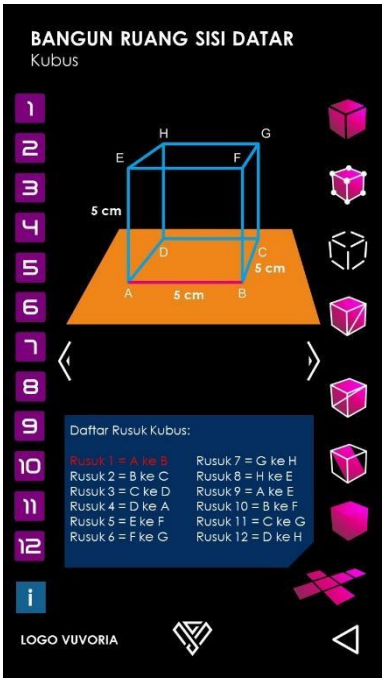

Figure 2. The Create Menu of Virtual Geometry

The design of the building scene on the flat side of the cube, or more precisely the visual display if the user hits the rib button, is shown on the left side of the cube, where there are buttons that function to reveal the rib when button 1 is clicked, the edges A to B will turn red. As soon as you click button 2, the edges B to C will also change color to red, and so on until reached the button 12.

Internal Validation Stage

Testing of product designs takes place both internally and externally, as well as in the field for products that have already been manufactured (Ozcakir & Cakiroglu, 2021). In accordance with the results of the test, the results of the validation of the mathematics lecturers were an average of 54.00 when converted to percent, i.e. 90.00 percent; the results of the validation of the mathematics teachers were an average of 53.00 when converted to percent, which is 88.33 percent; and the results of the validation of the mathematics students were an average of 51.00 or 85 percent; as a result, it was classified as "Valid". Testing by media experts was conducted by validator as the capacity as a lecturer in Informatics Engineering, and the validation results were acquired with an average score of 56.00 translated into percent to 93.33 percent based on the results. Afterwards, it is classified as "Valid," which means that the Virtual Geometry learning medium based on Augmented Reality is considered to be extremely valid for educational purposes. The average findings obtained by the validator are shown in the following Table 2.

Table 1. The Product Design

Validator	**Validator Value**		
	Score	**Percentage**	**Category**
Mathematics Lecturer	54	90,00	Valid
Mathematics Teacher 1	53	88,33	Valid
Mathematics Teacher 2	51	85,00	Valid
Computer Engineering Lecturer	56	93,33	Valid

Design Revision Stage

As a result of the material validator's proposals, the Virtual Geometry learning media received the following advice: preserve your existing technological skills in order to advance mathematics learning, particularly in Mathematics and other courses; and keep your existing technological skills in order to advance mathematics learning. The final recommendation made by the media Validator is the requirement for usage instructions. Results of the adjustment can be seen in the following figure: Figure 3.

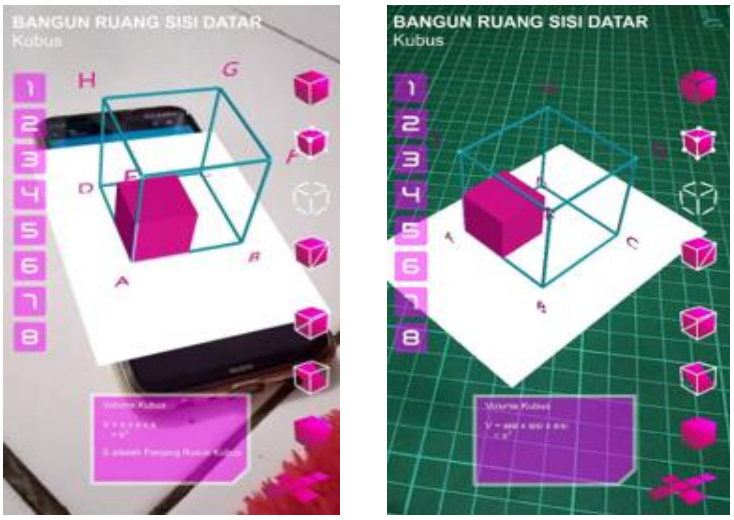

Figure 3(a) Development Design before revision; 3(b) Development Design after revision

Development Product Stage

Virtual Geometry learning media can be made with the help of software and hardware. The software used in the manufacture of geometric virtual products consists of seven software tools, they are: 1) Windows 10 May 2020 64-bit Operating System; 2) Unity 2020.1.0f1; 3) Microsoft Visual Studia 2019 16.7.30406.217; 4) Corel Draw X7 17.0.0491; 5) Microsoft Office Professional Plus 2019 16.0.13029.20308; 6) BlueStacks (64-bit) 4.220.0.4001; and 7) Blender 2.83.3. Secondly, for the hardware product. There are nine hardware used to make the product, namely: 1) Sony Xperia XZs; 2) Fujitsu A572/E Laptops; 3) Samsung Evo 250GB SSD; 4) 1TB Hard Disk Drive; 5) RAM 6GB; 6) Intel Core i5 Processor; 7) External Monitor 15.6 inch 720p (HD); 8) Logitech B100 Mouse; and 9) Webcam C270.

Subsequently, a User Interface (UI) is created as the next stage in the development process (UI) As shown in Figure 4, an example of the effects of creating a UI Virtual Geometry may be seen in action.

Figure 4. The Cube Object Part in Surface Area

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Following the completion of the UI design, the 3D model creation will begin. Here are a few examples of 3D models created with the Blender modeling software in figure 5.

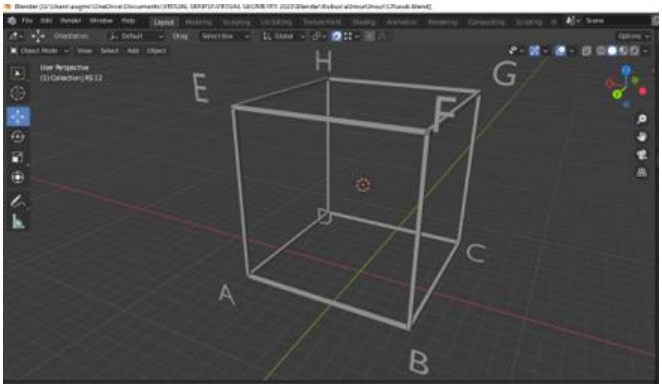

Figure 5. 3D Model of The Cube Ribs

Subsequently, after the user interface and 3D models have been completed, the next stage is to construct an application using the Unity software package. Figure 6 shows an example of how Virtual Geometry can be created.

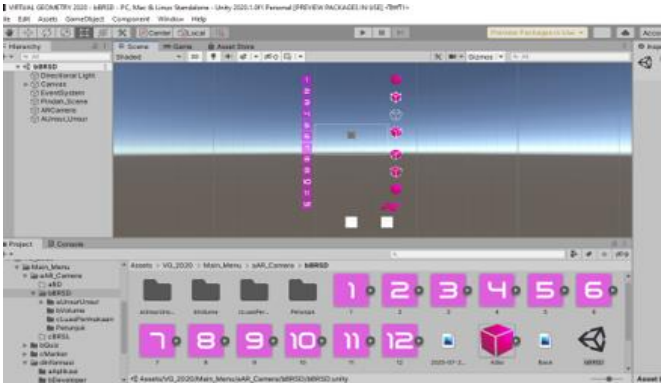

Figure 6. Camera for Augmented Reality Construct

Coding and construction are the final stages. All of the components that have been entered into Unity will be connected to one another in order for it to function as an application. After the coding is complete and there are no problems, the following step is to construct the virtual geometry, which is the final stage of the creation process. This can be seen in greater depth in the following illustration Figure 7.

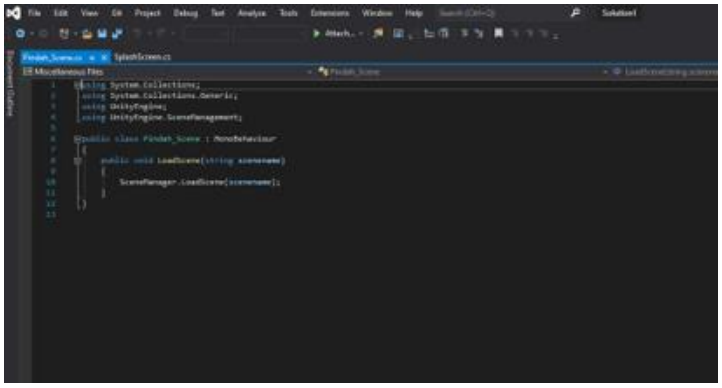

Figure 7. The Main Menu Coding

Limited Trial

Researchers put the Virtual Geometry learning media package through its paces in order to determine its suitability as a learning medium for cube material (Cabero-Almenara, Barroso-Osuna, & Martinez-Roig, 2021). A small batch of 15 studentss from Junior High School of 2 Pamarican, West Java, Indonesia were subjected to Media Virtual Geometry testing. Besides, the product was tested for the first time, and students were asked to complete a user reaction form. The practicality of learning media in terms of improving students' mathematics visual spatial abilities in cube material is the factor that is being evaluated.

Based on the results of the test, it was discovered that the average score was 12.48, which was converted to 83.2 percent, and the test was classified as "Practical," which means that students responded well in this context. According to the students, this Virtual Geometry learning media is practical and generates intriguing responses from them due to the fact that they are unfamiliar with the use of Augmented Reality.

This study used pre and post-test scores in the form of mathematical visual spatial ability questions for 15 students from Junior High School of 2 Pamarican, West Java, Indonesia to collect information on the results of their mathematical visual spatial abilities in mathematics. The average pretest yielded 16 outcomes, with the lowest score being 8 and the maximum value being 22. More information may be found in the following figure 8 and figure 9, which shows the results for each score.

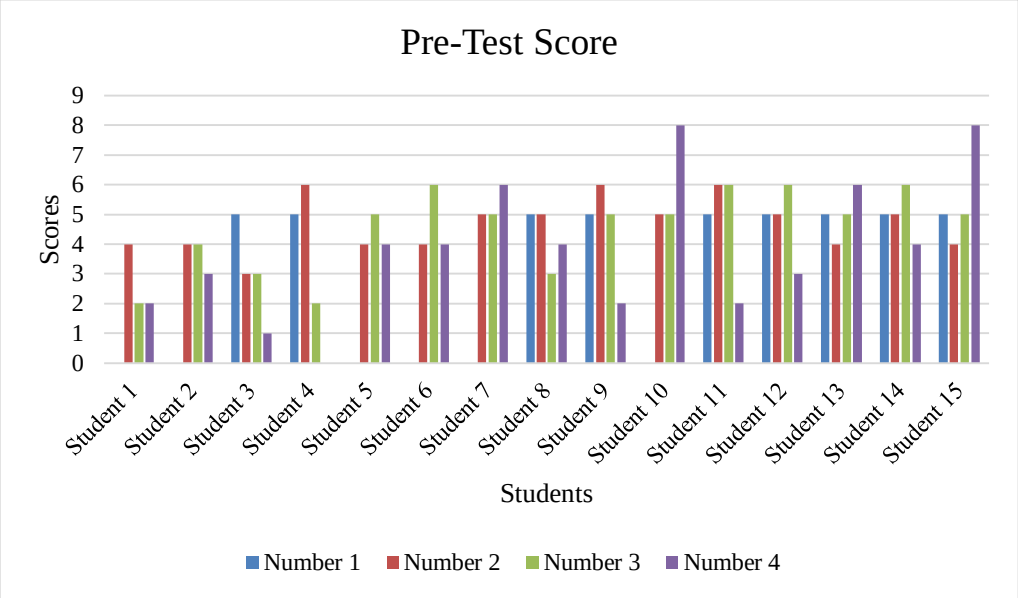

Figure 8. The Pre-Test Score

Based on figure 8, it can be determined that there are five interval classes, with each class interval lasting three minutes. The 17-19 range contains the greatest number of results, accounting for 33.30 percent of all values obtained (5 students out of 15 students). Also, the results from the average posttest show that the mean is 18.8 and that the lowest value is 12 and the highest value is 25. More information can be found in Figure 9, which shows more specifics.

According to the figure 9, the number of interval classes is five, with the length of each class interval being three minutes each. The interval 16-18 has the greatest number of values obtained, accounting for 40% of all values (4 students out of 10 students).

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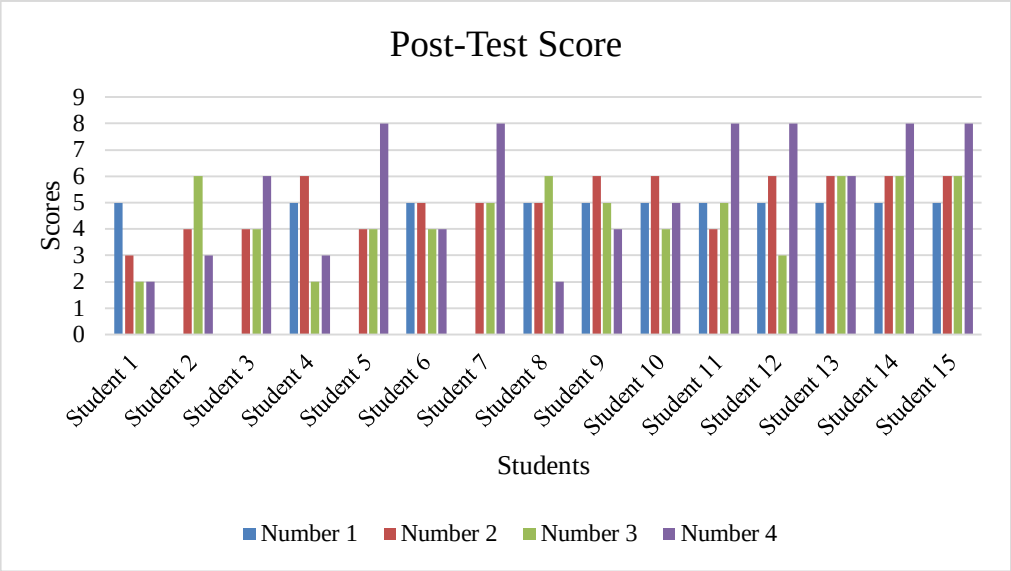

Figure 9. the Post-Test Score

As can be seen in the table 2, a descriptive statistic derived from the results of the pretest and posttest, as well as the growth in mathematical spatial ability, is presented. According to the data in the table 2, the average rise in scores derived from the pretest and posttest scores following the use of Virtual Geometry media increased by 2.8 percentage points.

Table 2. Pre-Test and Post-test Score

Tes	N	Xmin	Xmax	Average	Details
Pre-test	1	8	22	16	Before utilizing The Virtual Geometry media
Post-test	1	12	25	18,8	After utilized The Virtual Geometry media
Increase Score = Post-test score – Pre-test score = 18,8 – 16 = 2,8					

Based on these findings, it has been determined that learning geometry material in junior high school through the use of Virtual Geometry media has an impact on students' mathematical spatial abilities in mathematics. In other words, students at Junior High School of 2 Pamarican, West Java, Indonesia can benefit from the use of Virtual Geometry media to develop their mathematical spatial abilities. This is due to the fact that students are engaged and independent in the operation of Virtual Geometry media during the learning process, resulting in a more positive learning experience while visualizing geometric objects.

Augmented Reality (AR) is becoming more frequent and popular in schools and classrooms these days (Ahmad & Junaini, 2020). AR can help students develop their spatial abilities as well as their ability to reason logically. Interactive with virtual objects through augmented reality interfaces gives students with a more intuitive and natural manner of dealing with virtual geometry as they progress through their education. Various varieties of AR can be used to increase spatial reasoning and understanding of 3D shapes when learning 3D geometry, and each style has its own advantages. Utilizing suitable tools to visualize and interact with virtual geometry leads to a greater understanding of solids (Voronina et al., 2019).

Meanwhile, Elsayed and Al-Najrani (2021), AR can help kids and students develop their creative abilities as well as their ability to reason logically. Students can freely rotate a 3D shape and directly edit even more complicated 3D structures using Virtual Geometry to better grasp the geometrical work that has been handed to them by a teacher using Virtual Geometry. What's more, Kaufmann and Schmalstieg (2017), it serves as a link between the virtual, abstract world of solids and the natural environment, as well as the 3D things that exist all around them. AR is the ideal educational technology

to assist teachers in igniting students' curiosity and facilitating meaningful discovery, which is necessary to begin comprehending Virtual Geometry in the first place.

Furthermore, according to the findings of this study, AR classes have an impact on students' views toward geometry. Studentss who learn geometry through AR have more favorable attitudes than students who learn geometry through traditional methods. The vast majority of responders express a strong interest in and excitement in comprehending augmented reality content (Schutera et al., 2021). In spite of this, studentss displayed a relatively low degree of confidence in the initial phase because they were still unfamiliar with the entire AR idea. But, in the end, they discovered that the learning process was enjoyable and interactive, and that it inspired them to learn more about geometry. AR benefited students in gaining a better understanding of the topic content and increased their enthusiasm for the learning process while in the classroom. The findings are consistent with those of studies conducted by Su, Cheng, and Lai (2022), and Del Cerro Velázquez and Méndez (2021), which found that augmented reality can assist students in understanding, increasing learning motivation, positive attitude, and pleasure in the learning process.

In a 2021 study, Moreno et al., (2021) found that AR technology can be used as an alternative learning tool to enhance students' learning motivation by requiring them to look for relevant information on the topic they are studying on their own time. Students are given opportunities to investigate their mathematics concepts rather than being spoon-fed arithmetic knowledge during the AR learning process (Hamzah et al., 2021). In education, the use of any technology tool is not necessarily limited to newness and innovation alone, but rather to its effectiveness in engaging and motivating students as well as in establishing a pleasant learning environment (Schmalstieg et al., 2020). Teachers will benefit from being aware of their students' attitudes toward geometry because they will be able to identify students who have negative attitudes toward geometry and take the necessary precautions (Vakaliuk, Shevchuk, & Shevchuk, 2020). Knowing their students' attitudes toward geometry will help them identify students who have negative spatial abilities toward geometry.

CONCLUSION

Students' responses in learning to use Virtual Geometry media were 83.2 percent, which can be interpreted as indicating that students respond very well and that Virtual Geometry is being used in practice, according to the findings of a study on the development of Augmented Reality (AR) learning media to improve junior high school mathematical spatial abilities on geometry material. The conclusions are as follows: 1) Based on the results of the study on the development of Augmented Reality (AR) learning media to improve junior high school mathematical spatial abilities on geometry material, the conclusions are Students' experiences with geometry in junior high school are made more relevant by the usage of Virtual Geometry media, which allows them to examine a greater variety of genuine geometric objects. The following recommendations for future research: 1) The screen resolution section of virtual geometry learning media still has shortcomings; when developing the application, pay attention to the screen resolution so that it can be used on all devices; 2) Another drawback is the depth of mathematical studies; therefore, it is recommended that more emphasis be placed on the mathematical aspects of virtual geometry learning media in order to conduct further research;

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