

Unlocking Math Skills: The Argeo Math App for Enhanced Mathematical Problem-Solving

Yulia Maftuhah Hidayati¹, Anton Adi Suryo Kusuma², Muhammad Exsel Wimpy Wibosono³, and
Sylviana Ika Safitri⁴

^{1,2,3,4}Universitas Muhammadiyah Surakarta

*Corresponding Author's email: ymh284@ums.ac.id

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Keywords:	Abstract
<p><i>argeo Math;</i> <i>application;</i> <i>geometry;</i> <i>problem-solving;</i> <i>elementary school</i></p>	<p><i>This study aimed to design and evaluate the effectiveness of "Argeo Math," a novel learning media application, in improving mathematical problem-solving abilities in elementary school students. Employing a research and development (R&D) methodology with a limited trial stage, the research examined the feasibility, practicality, and impact of Argeo Math on student performance. Positive validation results affirmed the potential of Argeo Math. Material experts awarded the application a score of 55 (84.6%), while media experts gave it an overall score of 81 (90%). The effectiveness testing demonstrated significant differences between classes using Argeo Math and those using traditional methods. Students utilizing Argeo Math achieved an average score of 78.03%, while those in the control group scored 11.36%. This represents a substantial improvement of 66.67% in problem-solving skills. Additionally, the practicality assessment categorized Argeo Math as "highly practical," with a score of 76.03%. The novelty of this research lies in the development and evaluation of Argeo Math, a unique application specifically designed to enhance elementary students' mathematical problem-solving abilities. The positive findings suggest that Argeo Math holds significant potential as a valuable tool for improving</i></p>

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mathematical performance and fostering a deeper understanding of problem-solving strategies in elementary education.

INTRODUCTION

Background of the Study

Mathematics education plays a crucial role in equipping students with knowledge by fostering conceptual understanding, systematic problem-solving skills, and real-world application of mathematical concepts. Notably, well-designed mathematics learning experiences should prioritize the development of higher-order thinking skills (HOTS) (Budiman & Jailani, 2014). HOTS aim to nurture a persistent problem-solving attitude and encourage students to creatively approach and overcome challenges (Budiman & Jailani, 2014; Kurniati et al., 2016). Lailly and Wisudawati (2015) identify several key mathematical abilities encompassed within HOTS, including problem-solving, conceptual understanding, reasoning, creativity, critical thinking, representation, communication, and making mathematical connections.

The demands of 21st-century education necessitate the cultivation of advanced thinking skills, effective problem-solving strategies, and responsible decision-making abilities (Pertwi & Rizal, 2020). Consequently, contemporary learning environments should emphasize the development of 4C skills: Critical thinking and Problem-solving, Communication, Collaboration, Creativity, and Innovation. Among these essential skills, problem-solving stands out as a cornerstone competency for students to hone. Wahyudi and Anugraheni (2017) define problem-solving as the capacity to navigate and overcome roadblocks to achieve a desired outcome. Given the inherent requirement for critical thinking in solving mathematical problems, mathematics education presents itself as a valuable avenue for nurturing problem-solving abilities in elementary school students.

Problem-solving ability is essential in solving various problems, especially Mathematics. Problem-solving skills are one of the goals of Mathematics learning in schools, namely learning how to think and reason to conclude, developing problem-solving skills and developing communication skills, believing or communicating ideas orally, in writing, through pictures or graphs, maps, and diagrams (Sumartini, 2016). It can also open up a different point of view and discover unexpected ideas (Fitriana et al., 2016; Suripah & Sthephani, 2017). Problem-solving abilities correlate with developments in the modern era. Problem-solving ability is essential in learning Mathematics. Many students are still experiencing difficulties in solving mathematical problems. The level of problem-solving ability is influenced by several factors, including initial experience, prior knowledge of Mathematics, motivation, and the structure of the problems given to students. In addition, the low problem-solving abilities of students are also influenced by the focus of students who are only on content rather than mastering problem-solving abilities. The low ability of students' mathematical problem solving will impact low achievement and student learning outcomes (Lien, 2016). Learning media is necessary to overcome this problem, which can help students construct their knowledge later.

Learning media is an instrument that can help the learning system and explain effectively the material presented to achieve perfect learning objectives. Along with technological advances, cell phones have developed into gadgets. As Calimag et al., (2014) pointed out, gadgets can help educators and broaden student inspiration. Gadgets can also work with human communication and access data assets anytime and anywhere. Astini (2020), revealed that using m-learning applications can help elementary school students learn through gadgets to obtain learning material anywhere and anytime. Along with the advancement of gadgets, innovations are also developing, significantly Augmented Reality (AR).

Problems of the Study

Among various mathematical topics, geometry presents a unique set of challenges for students. This stems primarily from the abstract nature of its subject matter, with concepts like squares, triangles, blocks, and boxes requiring strong spatial reasoning abilities (Sukma & Leelasantitham, 2022). This inherent abstraction is further compounded by students' difficulties in visualizing these abstract objects in their minds, a critical element of spatial intelligence (Sukma & Leelasantitham, 2022). This observation is corroborated by interviews with fifth-grade mathematics teachers in Surakarta City, who identified student difficulties in visualizing geometric shapes, nets, and structural frameworks as key hurdles in learning geometry.

Furthermore, traditional teaching methods and limited resources often hinder the effective delivery of geometric concepts. Classroom observations revealed a reliance on makeshift media and conventional methods, attributed to limited access to appropriate teaching tools. Additionally, time constraints frequently prevent teachers from exploring or implementing alternative media that could enhance the learning process (Nurdin et al., 2019; Nuraini et al., 2020). This reliance on direct instruction at the symbolic level overlooks the importance of visual aids and student-centered activities, leaving many students struggling to grasp the material (Nurdin et al., 2019; Nuraini et al., 2020).

However, opportunities exist to cultivate students' problem-solving abilities in geometry. Shifting away from teacher-dominated presentations towards student-centered activities that stimulate critical thinking and problem-solving can significantly improve learning outcomes. Ramdhani et al. (2014) and Rusnilawati & Gustiana (2017) emphasize the need for engaging learning materials and interactive approaches to capture student interest and facilitate comprehension. One crucial tool in achieving this is the implementation of effective learning media.

The use of learning media by using AR can animate students' attitudes in determining existing problems and situations, considering the idea of learning media to assist learning by handling the presence or absence of teachers in learning interactions so that the utilization and use of learning media can occur anywhere and anytime students need to do the learning system (Mustaqim, 2016). Advances in mobile phones and Augmented Reality innovation have created many new applications to aid learning. According to Wardani & Sari, (2015), many educators still have not changed and improved by using innovation in learning because instructors experience problems in making IT-based learning media. Students are familiar with various types of room designs. However, at the same time learning, the teacher often experiences students who do not understand the geometry of the material because this material requires students' creative abilities to imagine the type of room. Besides that, many students are overwhelmed by the educator's strategy in teaching because they convey material without teaching assistance.

Research's State of the Art

This research draws upon existing evidence indicating the potential of Android mobile applications in enhancing student engagement and learning outcomes in various domains. Studies by Fitriani et al. (2022), Rozi et al. (2021), and Subagyo et al. (2018) highlight the effectiveness of such applications in increasing children's interest and enjoyment in learning, particularly relevant for the present study focused on geometric formula recognition. Similarly, Aldi (2017) demonstrated the effectiveness of Android applications in attracting students' interest in learning about different types of animals. Beyond engagement, Mariani et al. (2021) found mobile learning media to be feasible for improving students' mathematical critical thinking skills. Furthermore, Mahuda et al. (2021) reported that Android-based Math learning media effectively increased students' problem-solving abilities using Smart Apps Creator. Building upon these findings, this research aims to combine the potential for improved critical thinking and problem-solving identified in previous studies to assess the effectiveness

of "Argeo Math," a novel Android mobile application designed to enhance both creative and mathematical thinking skills in the context of geometric formula recognition.

Gap Study & Objectives

The effectiveness of teaching and learning methods significantly impacts student understanding, particularly in challenging subjects like geometry. Traditional, monotonous methods identified by Nurdin et al. (2019) and Rahmawati (2022) can lead to student boredom, hindering engagement and learning outcomes. This is especially detrimental in geometry, where abstract concepts require clear visualization and engaging approaches.

To address these challenges, research has explored the potential of innovative learning media. The study by Trisanti and Iffah (2022), for instance, demonstrated the effectiveness of SAC-assisted Android-based space geometry learning media in improving students' proof abilities. Sulistyanto et al. (2023) further confirmed the validity and practicality of such media, making it a viable tool for enhancing learning outcomes.

Building upon this evidence, this research proposes the development of an Augmented Reality (AR)-based learning application for fifth-grade elementary school students in Surakarta. As Dinayusadewi and Agustika (2020), Mambu et al. (2020), Permatasari and Andayani (2021), and Syafril et al. (2021) highlight, AR technology seamlessly overlays virtual objects onto the real world through smartphones. This integration offers a promising avenue for enhancing learning effectiveness and efficiency, particularly in presenting abstract geometric concepts in a tangible and visually clear manner. As Pamoedji and Maryuni (2017) explain, AR can transform abstract geometric elements into readily observable forms, fostering deeper understanding and visualization.

Therefore, this research aims to develop and evaluate "Argeo Math," an AR-based learning application specifically designed to improve students' mathematical problem-solving abilities, with a focus on geometric concepts.

METHOD

Type and Design

The type of research used was research and development (R&D). The research model used is The Borg & Gall model. Stages of the model consist of ten steps, including Research and Initial Data Collection, Planning, Preliminary Product Development, Preliminary field testing, Initial Product Improvement (Main product revision), Field Trial (Main field testing), Operational Product Improvement, Operational Trial (Operational field testing), and Final Product Improvement, Dissemination (Sutama et al., 2022). This research was limited to the limited trial stage.

Data and Data Sources

This research was conducted at SD IT Muhammadiyah Al Kautsar, Gumpang, Kartasura. The research subjects were VA and VB class students consisting of 40 students and 2 fifth grade teachers. Media validation was obtained from lecturers who are experts in the IT field while material validation was obtained from fifth grade math teachers.

Data collection techniques

Data collection techniques in this research were validation sheet, practicality sheet, and tests. This research was limited to a limited trial phase.

Data analysis

The product produced by this research was the Argeo Math on spatial construction materials. The data obtained in this research was processed using qualitative and quantitative analysis techniques. This is used to test the feasibility and effectiveness of the Argeo Math.

The formula for calculating the average value of the assessment of each validator is as follows;

$$P = x 100\% \frac{F}{N}$$

Note:

- Q : Number of presentations
- F : Frequency of presentation
- N : Amount percentage

Arikunto (2010) modification in Karina et al. (2019) shows a table of validity criteria, which can be seen in Table 1.

Table 1. Validity Criteria

Percentage	Note
76% - 100%	Very Worth it
51% - 75%	Worthy
26% - 50%	Less Eligible
0% - 25%	Not feasible

The effectiveness test of Argeo Math media with the SPSS-assisted N-Gain test is used to determine the effectiveness of using Argeo Math media seen from mathematical problem solving. Normalized Gain or N-Gain score is done to determine the effectiveness of using a particular method or treatment in research, in this case, to determine the effectiveness of using Argeo Math learning media in learning. Table of interpretation formula according to Hake (1998) can be seen in the Table 2.

Table 2. Classification of the Normalized Gain Value

Average Gain Normalized	Classification	Level of Effectiveness
$\langle g \rangle \geq 0.70$	High	Effective
$0.30 \leq \langle g \rangle \leq 0.70$	Medium	Effective enough
$\langle g \rangle < 0.30$	Low	Less effective

Quantitative data of student response questionnaires to Argeo Math media in the form of student response scores are obtained in the form of categories consisting of 5 response options, namely strongly agree, agree, doubt, disagree, and strongly disagree. The Likert scale in Nugroho, (2021) scoring table is presented in the Table 3.

Table 3. Table Criteria for Assessing Students' Attitude towards Mathematics

Score	Score Interval	Category
A	$X > 134,4$	Very Good
B	$108,8 < X \leq 134,4$	Good
C	$83,2 < X \leq 108,8$	Enough
D	$57,6 < X \leq 83,2$	Less
E	$X \leq 57,6$	Very Less

RESULTS

The initial research phase involved qualitative data collection through observations and interviews with an elementary school teacher in Surakarta. Findings revealed a reliance on traditional textbook-based methods in geometry instruction, potentially contributing to student boredom and

hindering their ability to differentiate between area and volume of geometric shapes. Recognizing the complexity of the material and the need for student engagement, the authors developed Argeo Math, an interactive mobile application designed to support elementary school students' learning of geometric concepts. Argeo Math offers convenient access without requiring account creation or synchronization. At the planning stage, the application was conceptualized around five key components: augmented reality (AR) features, learning materials, quizzes, developer information, and user instructions. UNITY, a popular game development platform, served as the primary development tool, facilitating the creation of the integrated AR elements.

The initial product stage focused on establishing core functionalities, particularly within the AR section. Students access the AR feature through a dedicated "scan now" menu. By scanning pre-designed block and cube cards, corresponding virtual objects are projected onto the user's smartphone screen, allowing for 3D visualization. The scanned block card displays a virtual, manipulable block accompanied by its dimensions, while the cube card reveals a virtual cube with labeled sides. Figure 1 illustrates the main menu design, while Figure 2 showcases the AR visualization in action. Second, on the Lesson menu. The lesson menu contains material for cube nets, beam nets, cube volumes, and block volumes. In the material for nets of cubes, there are definitions of nets, definitions of cubes, and examples of cube nets. In the material of beam nets, there are definitions of beams, characteristics of beams, and examples of pictures of beam nets. In the volume of a cube, there is an explanation of the volume of a cube, an example of a volume cube problem. In the material on the volume of blocks, there is an explanation and examples of questions about the volume of blocks. The materials and sample questions can be seen in Figure 3 and Figure 4.

Figures 2. AR beam view



Figures 3. Display materials

Figures 1. The main menu of the Argeo Math application

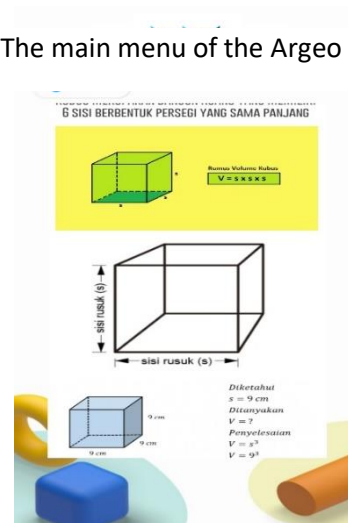


Figure 4. Display of sample questions

Third, the quiz menu. There are 20 practice questions with the materials of cube nets, beam nets, cube volume, and block volume. This exercise has a timer for working on the questions, which is 1 hour 30 minutes. Your maximum score is 100, with one correct question worth 5. The quiz questions on the Argeo Math application consist of HOTS questions. The HOTS questions have previously been tested for validity and show that the questions are valid and feasible. The quiz display can be seen in Figure 5.



Figure 5. Quiz display

The fourth feature is the information feature. We will open the information feature; this feature contains information about the creator of the Argeo Math. Display information can be seen in Figure 6.

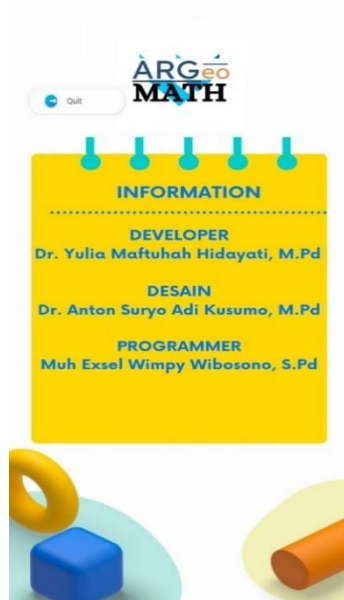
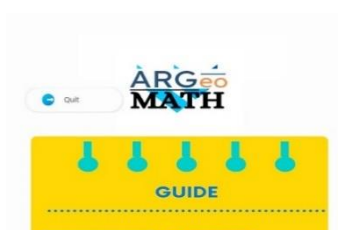


Figure 6. Information feature display

The fifth feature is the guide feature. We will open the guide feature; this feature contains information on the features in the Argeo Math. Next, there is the Quit feature. This feature helps you exit the application or end your activity with the Argeo Math. Every time you enter a feature in the



application, there is an exit button to exit one of the features. The guide feature can be seen in Figure 7.

Figure 7. Display of the guide menu

After developing the product draft, the next step is the initial trial of the product, which one teacher carries out as a material expert and one lecturer as a media expert. The percentage of eligibility from material experts can be observed in Table 4.

Table 4. Percentage of Eligibility from Material Experts

Aspect	Indicators	Score
1	Learning	
	Relevance of material with basic competence	4
	Material suitability with indicators	5
	Clarity of material description	5
	Adequacy of training	4
2	Content	
	Ease of use of learning media	5
	Clarity of presentation of the material	5
	Material truth	5
	The use of language is easy to understand	5
	The material presented is interesting	4
	Image clarity to clarify content	4
The images presented support	4	
Amount		55
Percentage		84.6 %
Criteria		Very Worth it

Table 4. shows that the results of the validation of material experts on the development of Argeo Math are in the very appropriate category. The validation results get a score of 55 with a percentage of 84.6% from the learning aspect and content. The clarity of the images to clarify the content gets a score of 4 because there are questions where the images are not transparent or blurry in the application; this is supported by research which states that pictures are a tool to accelerate the process of teaching and learning activities as well as to achieve learning goals (Amir, 2016). The percentage of eligibility from the media expert's validation can be seen in Table 5.

Table 5. Percentage of media experts

Aspect	Criteria	Score
efficiency	The media workflow is easy to understand	5
	Learning media is easy to use in the operation	5
	Simple program operation	5
Appearance	Clarity of instructions for using the media	4
	Consistency of features in the media	4
	Students easily understand language	5
	The attractiveness of the design view	4
	The suitability of the images and aspects in the media program is interesting	4
	Accuracy of color selection and composition	4
	Clarity of text in learning media	4
	The placement of the menus in the media is correct	4
Technical Quality, Program	Learning media is not boring	5
	The material presented is based on the learning objectives	5
Effectiveness	Evaluation accuracy in the Exercise menu	4
	The entire program is presented in a systematic and concise manner	4
Software	Maintainable (can be managed easily)	5
	Usability (easy to use and simple to operate)	5
	Reusability (learning media can be reused to develop learning media)	5
Amount		81
Percentage		90%
Criteria		Very Worth it

Table 5 shows that the results of the validation of media experts on the development of Argeo Math are in the very appropriate category. The validation results get a score of 81 with a percentage of 90% of aspects of technical quality and program effectiveness.

Limited Trial Analysis Results

Data on the practicality of Argeo Math was collected through two means: (1) teacher and student assessments of the learning device's feasibility and (2) observations of the learning implementation during a limited trial. This section focuses on the analysis of students' practicality assessments. These assessments were conducted through a post-intervention survey administered to

students following their brief learning experience with Argeo Math. The survey captured their feedback on the feasibility of using the application and their overall impressions of the learning process. Table 6 summarizes the key findings of this student assessment.

Table 6. Categories of Student Response Questionnaire Results on Limited Trial

Assessment Aspect	Total Score	Average score	Category
Argeo Math Media	762	38,1	Very good
Learning Process	437	24,3	Good

Improved Problem-Solving Ability

Table 7 shows the results of data analysis that was carried out using Argeo Math and without Argeo Math. The results indicated improved students' problem-solving abilities in geometric material using Argeo Math media.

Table 7. Effectiveness Data

Class	N	Mean of Pretest	Standart Deviation	Mean of Posttest	Standart Deviation	Gain	Description
Using Argeo Math	20	2.66	1,274	17.96	2,263	78.03%	Effective
Without Argeo Math	20	2.88	1,288	5.17	1,341	11.36%	Ineffective

Note, maximum value: 20

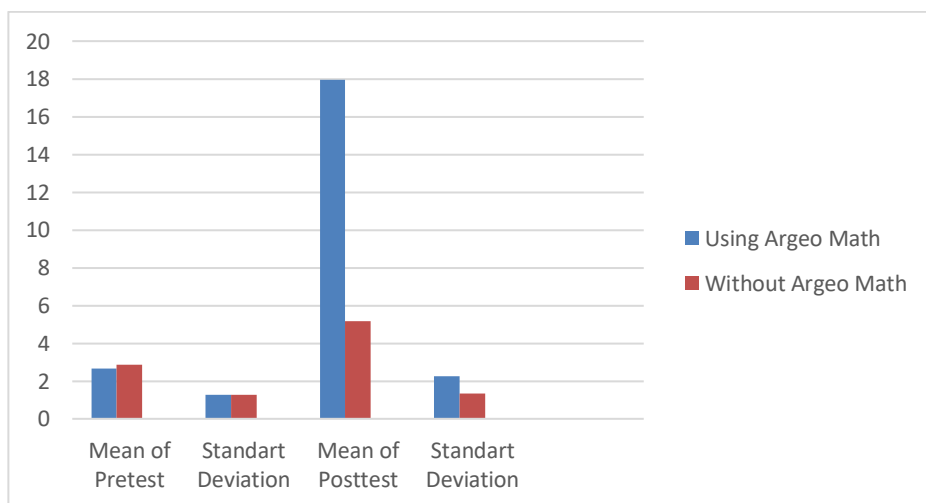


Figure 8. bar chart of effectiveness data

Table 7 shows that the increase in students' problem-solving abilities in classes with Argeo Math is higher than in classes without Argeo Math. The data also shows that elementary schools in classes with Argeo Math have an increase in the distribution of the previous data (SD = 1.274 to SD = 2.263), while elementary schools in classes without Argeo Math have a minor increase in distribution (SD = 1.288 to SD = 1.341). Then, the class with Argeo Math has a G value more significant than that without Argeo Math. This shows that improving students' problem-solving abilities in classes with Argeo Math

is more effective than in classes without Argeo Math. By interpreting the Hake's Gain formula, a value of 78.03% is obtained in the practical category.

The value of increasing problem-solving ability, g , was previously tested for normality. To test the normality of the two classes using the Kolmogorov-Smirnof method. The results show that both classes are typically distributed at a significance level 0.05. Table 8 shows the results of the independent T-test analysis

Table 8. Independent T-Test analysis results

	T-Test for Equality of Means		
	Q	df	Sig (2-tailed)
Equal variances assumed	-20.101	38	.000

This research indicates that Argeo Math is efficacious in improving problem-solving abilities. Based on the T-test in Table 8, the asymp. sig. $0.000 < 0.05$, indicating that the problem-solving abilities of students in classes that use Argeo Math are more effective than those that do not use Argeo Math.

DISCUSSIONS

Argeo Math offers a readily accessible interface specifically designed for fifth-grade elementary school students. Its core focus lies in enriching learners' understanding of spatial concepts, particularly volume and nets. The application is equipped with several features that demonstrably enhance teaching and learning experiences within the mathematics curriculum. These features and the overall benefits of Argeo Math resonate with the findings of previous research. Studies by Astra et al. (2015), Hadiyanti et al. (2021), Sahronih et al. (2019), and Suryani et al. (2022) highlight the numerous advantages of technology-based learning media, including fostering curiosity, boosting learning motivation, facilitating comprehension of abstract and complex concepts, capturing students' attention, and providing increased flexibility in learning locations and timeframes.

Furthermore, the content presented in Argeo Math targets achieving a learning objective score of 5, aligning with the existing curriculum and existing research on effective learning materials. Susanti (2018) emphasized the importance of tailoring learning materials to the established curriculum and student learning goals. This aligns with the broader consensus established by Hanum (2013) and Isnawardatul (2017), who emphasize the crucial role of considering and aligning learning objectives with the chosen learning media to ensure effectiveness.

Ultimately, learning media that demonstrably aligns with learning objectives and prioritizes effectiveness in enhancing student comprehension has the potential to significantly improve student motivation. As Wijaya et al. (2020) and Dwijayani (2019) point out, well-designed learning media serves as a valuable tool that bridges the gap between students and complex concepts, ultimately contributing to effective and efficient learning outcomes. Nurrita (2018) and Sahronih et al. (2019) further expand on this notion, highlighting the role of learning media as a resource for students to actively engage with the provided information and build upon their knowledge base.

Developing a comprehensive understanding of geometry requires students to master key concepts, apply procedures effectively, and perform accurate calculations. However, traditional, textbook-based learning often presents challenges in visualizing and differentiating abstract geometric shapes. As Rizkianto et al. (2013) highlight, relying solely on memorizing verbal descriptions without experiencing concrete, real-world examples hinders students' comprehension and long-term retention of geometric concepts.

This research addresses this challenge by leveraging the potential of Augmented Reality (AR) through the "Argeo Math" application. Argeo Math provides students with the opportunity to visualize geometric structures in a realistic and interactive manner. By displaying dynamic, moveable three-dimensional models directly on their mobile devices, Argeo Math fosters deeper engagement and understanding compared to static textbook images. Additionally, the application incorporates engaging features such as short explanations, interactive quizzes, and discussion prompts to further reinforce learning and assess mastery of the material.

For instance, Argeo Math's cube unit utilizes visually appealing color schemes and practical examples to guide students through solving real-world cube problems. The unit includes step-by-step demonstrations for finding cube nets and interactive quizzes presented with exciting colors, fostering active learning and promoting problem-solving skills. This innovative approach to geometry education holds significant potential for enhancing student engagement, comprehension, and ultimately, their ability to solve mathematical problems effectively.

CONCLUSION

Based on the research results on developing Android-based learning media, Argeo Math is suitable for learning and can improve mathematical problem-solving abilities. This is supported by the results of validation results from material experts supported this statement with a score of 55 and a percentage of 84.6%, and validation from media experts with an overall score of 81 and a rate of 90%. The effectiveness value in the class without argeo math media has a score of 11.36%, in contrast to the class using argeo math media which has a score of 78.03%. Classes with Argeo Math have a effectiveness value greater than classes without Argeo Math, scoring 76.03% in the practical category. The novelty of this research is in the application created, namely Argeo Math. Suggestions for future researchers: Argeo Math research can be continued until the dissemination stage and teachers can create unique and innovative learning media in learning math. This research contributes to facilitate the process of teaching and learning activities of geometry. Teachers use this media to facilitate the explanation of geometry material.

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