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# Enhancing Conceptual Understanding and Learning Interest in Geometry through Augmented Reality-Based Learning Media

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***Abstrak***

*Penelitian ini bertujuan untuk mengembangkan media pembelajaran berbasis Augmented Reality (AR) dalam mata kuliah geometri untuk meningkatkan pemahaman konsep dan minat belajar mahasiswa. Penelitian ini menggunakan model penelitian dan pengembangan (R&D) dengan prosedur pengembangan media mengikuti model ADDIE (Analysis, Design, Development, Implementation, Evaluation). Subjek penelitian melibatkan mahasiswa program studi Pendidikan Matematika di salah satu perguruan tinggi di Indonesia. Data dikumpulkan melalui instrumen lembar validasi dan tes efektivitas, yang diuji validitas dan reliabilitasnya menggunakan uji* paired sample t-test*. Hasil penelitian menunjukkan bahwa media pembelajaran AR yang dikembangkan mendapatkan skor validasi yang sangat baik (4,2/5) dari para ahli dan menunjukkan efektivitas yang signifikan dalam meningkatkan pemahaman konsep geometri (t = 15,23, p < 0,05) serta minat belajar mahasiswa (t = 12,76, p < 0,05). Penggunaan AR dalam pembelajaran geometri terbukti meningkatkan keterlibatan mahasiswa dan membuat konsep-konsep abstrak menjadi lebih mudah dipahami. Hasil ini sejalan dengan penelitian sebelumnya yang menunjukkan bahwa AR dapat meningkatkan kualitas pembelajaran, terutama dalam materi yang kompleks seperti geometri. Penelitian ini memberikan bukti empiris mengenai potensi AR dalam pendidikan tinggi dan menyarankan penerapan lebih luas di berbagai disiplin ilmu untuk meningkatkan pemahaman dan motivasi mahasiswa.*

**Abstract**

This study aims to develop Augmented Reality (AR)-based learning media in geometry courses to enhance students' conceptual understanding and learning interest. This research uses a Research and Development (R&D) methodology with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) for media development procedures. The subjects of the study involved students from the Mathematics Education program at a university in Indonesia. Data were collected through validation sheets and effectiveness tests, with validity and reliability tested using paired sample t-tests. The results showed that the AR-based learning media developed received an excellent validation score (4.2/5) from experts and demonstrated significant effectiveness in improving conceptual understanding of geometry ($t = 15.23$, $p < 0.05$) as well as students' learning interest ($t = 12.76$, $p < 0.05$). The use of AR in geometry learning was found to increase student engagement and make abstract concepts easier to understand. These findings are consistent with previous studies showing that AR can enhance the quality of learning, particularly in complex subjects such as geometry. This study provides empirical evidence regarding the potential of AR in higher education and suggests broader implementation across various disciplines to improve students' understanding and motivation.

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## INTRODUCTION

Mathematics education, particularly in the domain of geometry, continues to face a series of challenges related to the comprehension of abstract and complex concepts. One of the primary difficulties encountered by university students lies in visualizing three-dimensional geometric objects in space. This difficulty often leads to frustration and a decline in learning motivation (Johnston & Hunter, 2018). Traditional instructional methods that typically rely on visual aids such as flat images or physical models, although effective in certain contexts, are frequently insufficient in facilitating a robust conceptual understanding of abstract geometric forms and ideas (Cai et al., 2017). Global data indicate that students often struggle with geometric and other mathematical concepts, which contributes to low interest in these subjects. For example, a study conducted by Borasi et al. (2017) in the United States found that over 40% of students had difficulty grasping fundamental geometric concepts, such as the relationships between two-dimensional and three-dimensional shapes, and the application of geometric theory in real-world contexts. This conceptual struggle significantly undermines students' motivation to engage with mathematics and leads to lower academic achievement in geometry-related courses. In the Indonesian context, research by Setiawan et al. (2018) revealed similar challenges, indicating that university students frequently struggle with geometric topics, especially those involving spatial visualization and spatial relationships. The study also noted a tendency among students to avoid subjects perceived as difficult, such as geometry, which negatively affects their enthusiasm and persistence in learning the subject. A survey conducted across several Indonesian universities further revealed that geometry is regarded as one of the most challenging subjects, with approximately 35–40% of respondents reporting significant difficulties in understanding the material (Baharuddin, 2019). These findings underscore the necessity for innovative instructional approaches that not only enhance conceptual understanding but also foster greater student engagement and interest in geometry learning.

Improving student interest and comprehension in geometry learning depends not only on the quality of instruction but also on the manner in which learning materials are presented. Several studies have highlighted that traditional approaches relying on conventional teaching methods are often inadequate in enhancing students' understanding and interest in mathematics, particularly in geometry. For instance, Hidayat et al. (2020) argue that conventional instructional methods, which emphasize verbal and theoretical delivery, are less effective in helping students grasp abstract geometric concepts. In contrast, more interactive and visually oriented approaches—such as those supported by Augmented Reality (AR) technology—can aid students in visualizing difficult concepts more clearly and intuitively. This suggests the importance of innovating instructional media that address both conceptual comprehension and learner motivation simultaneously.

Augmented Reality (AR) technology offers a promising solution to these pedagogical challenges. AR integrates virtual elements into the physical environment using digital devices such as smartphones or tablets, enabling users to interact with virtual objects within their real-world surroundings (Azuma, 2019). In educational contexts, AR can transform the way students perceive and interact with learning content. It provides clearer and more dynamic visual representations of geometric objects, allowing students to observe three-dimensional figures from multiple perspectives and engage with them directly—an interaction that is rarely possible through traditional teaching methods (Huang et al., 2016; Muna et al., 2021). As such, AR has the potential to improve students' understanding of abstract geometric concepts—such as shape, space, symmetry, and transformation—in a manner that is both intuitive and accessible.

Research conducted by Marzuki et al. (2019) supports the assertion that AR technology can enhance students' comprehension of challenging mathematical content, particularly in geometry. In their study, students who engaged with AR applications demonstrated significant improvements in conceptual understanding, especially in visualizing three-dimensional geometric objects. Moreover, AR was found to increase student interaction with learning materials, thereby enhancing the overall learning experience (Bower et al., 2017). Additional findings from Griffiths et al. (2019) emphasized the effectiveness of AR in developing students'

spatial reasoning skills, which are critical for success in geometry. These conclusions are further supported by Saeed et al. (2020), who highlighted that AR in geometry education not only improves conceptual comprehension but also motivates students to invest more effort in learning.

Another international study by Piller et al. (2018) identified the significant potential of Augmented Reality (AR) in enhancing conceptual understanding in mathematics education, particularly in challenging topics such as geometry. The study revealed that students who utilized AR in learning geometry showed a notable improvement in spatial conceptual comprehension compared to those who engaged with traditional instructional methods. Furthermore, the study indicated that AR not only improved conceptual understanding but also enhanced student engagement and motivation. Learners involved in AR-based instruction reported increased interest and enthusiasm for learning, which directly contributed to a higher level of learning motivation. Similar findings were reported by Bower et al. (2017), who asserted that AR-based learning could stimulate academic interest and provide a more engaging learning experience, leading to increased student participation during the learning process.

On the other hand, student learning interest is often overlooked in educational research despite its substantial impact on learning outcomes. Learning interest influences the depth of student engagement and their perseverance in facing academic challenges (Setiawan et al., 2018). A decline in interest in mathematics learning, especially geometry, is frequently attributed to boredom and perceived irrelevance to daily life (Baharuddin, 2019). Consequently, incorporating advanced technologies such as AR presents a promising solution to this issue by creating more enjoyable and engaging learning experiences. The study by Piller et al. (2018) indicated that the use of AR in education can elevate students' interest and motivation, as AR incorporates gamification and interactivity—elements often absent in conventional learning environments.

Despite the growing body of literature highlighting the benefits of AR in improving conceptual understanding and learning motivation, its implementation in educational settings still faces numerous challenges, particularly in the development of effective and appropriate learning media. Some studies point out that although AR holds great potential, the availability of well-designed AR-based learning resources that are both pedagogically sound and acceptable to students remains limited (Huang et al., 2021). Effective utilization of AR in mathematics instruction, especially geometry, demands careful design—learning experiences should be clearly structured, easily comprehensible, and aligned with existing curricula. Research by Hamid et al. (2021) underscores the importance of instructional design that considers learning objectives and user competencies to ensure that AR provides maximal educational benefits. Furthermore, integrating AR into the curriculum necessitates adequate training for both instructors and students to optimize its pedagogical effectiveness.

In Indonesia, the integration of technology into mathematics education—particularly AR—is still in its developmental and exploratory stages. Nonetheless, several local studies have demonstrated the promising potential of AR to enhance students' motivation and conceptual comprehension. For example, research conducted by Khoo et al. (2020) at Universitas Negeri Yogyakarta reported that students learning geometry through AR applications exhibited significant improvement in understanding geometric concepts, particularly in visualizing three-dimensional objects. Moreover, 85% of the students involved in the study reported increased interest and motivation to learn after engaging with AR-based learning media. These results are consistent with findings from a survey conducted by Nurhayati et al. (2021), which revealed that the use of AR in geometry learning enhanced both student interest and motivation, with approximately 90% of respondents indicating greater interest in mathematics after experiencing AR-enhanced instruction.

One of the most critical aspects in the development of AR-based instructional media is its impact on students' learning interest. High levels of interest can foster active student engagement in the learning process, which in turn can improve academic performance. AR, with its interactive visualization features, is expected to generate more meaningful and relevant learning experiences, thereby rekindling interest often diminished by the perceived difficulty or dullness of mathematical content (Bower et al., 2017). In this regard, research by Khoo et al. (2020) highlights that well-designed AR instructional tools can positively influence learning interest, as

AR enables learners to experience more immersive and contextualized learning, reducing the gap between theoretical content and practical application in mathematics education.

From the aforementioned discussion, it is evident that the development of AR-based geometry instructional media holds considerable promise for enhancing both conceptual understanding and student interest in learning. Although numerous studies have demonstrated the effectiveness of AR in improving comprehension and motivation, there remains a gap in the development and implementation of AR applications that are pedagogically effective and aligned with student needs and curricular goals (Griffiths et al., 2019). Therefore, the present study aims to develop AR-based instructional media for geometry that not only enhances conceptual understanding but also increases student motivation and interest. Additionally, this study seeks to evaluate the effectiveness of such media within the context of higher education.

This research is expected to contribute to the advancement of innovative technology-based instructional media, particularly in the teaching and learning of mathematics in higher education. Furthermore, the findings of this study are anticipated to offer new insights into the application of AR in mathematics education and serve as a reference for the development of AR-based instructional tools applicable across various disciplines that involve abstract and complex concepts.

## METHOD

### *Research Design*

This study employs a Research and Development (R&D) approach aimed at developing an Augmented Reality (AR)-based learning medium to enhance students' conceptual understanding and learning interest in geometry courses. The R&D model was chosen because of its primary focus on the development of practical products that can be implemented in real educational settings (Sugiyono, 2017). The development process in this study follows the ADDIE model, one of the most widely used instructional design models in the field of education. The ADDIE model consists of five key phases: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009).

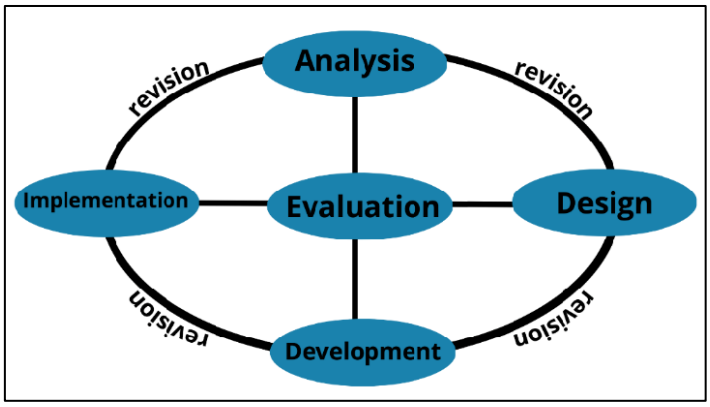


**Figure 1.** ADDIE Model

In the first phase**, Analysis**, the researcher identified the existing problems, namely the low level of students' conceptual understanding and interest in learning geometry. The researcher also conducted a needs analysis regarding learning media that are suitable for students' characteristics and instructional goals. Based on this analysis, the objective was formulated to develop an AR-based medium capable of improving both aspects.

The second phase, **Design**, involves designing the AR-based learning medium. During this phase, the researcher planned features to be included in the AR application, such as three-dimensional geometry object visualizations, interactive components that allow students to engage with these objects, and alignment with the existing curriculum. The design process also included the creation of a storyboard and a user interface layout that is intuitive for students to use.

In the **Development phase**, the researcher developed the previously designed learning media into a usable product for instructional purposes. This process involved programming and initial testing of the AR media to ensure that all features functioned properly and as intended. During this phase, a limited trial was also conducted with several students to gather feedback on the usability and effectiveness of the developed media.

**The Implementation phase** is the stage in which the developed learning media is applied in classroom instruction. Here, the finalized AR media was used by students during geometry lessons to determine the extent to which it could enhance their conceptual understanding and interest in learning. The trial was conducted through learning activities that actively involved students in the use of the AR media.

The final phase, **Evaluation**, involves assessing the effectiveness and feasibility of the implemented learning media. The researcher conducted evaluations to determine whether the developed AR media could improve students' conceptual understanding and learning interest. This evaluation was carried out by collecting data through observations, interviews, and questionnaires completed by the students.

The ADDIE model has been proven effective in the development of educational media, as demonstrated in research by Kurniawan et al. (2020), who developed an AR-based learning application for mathematics in Indonesia. This study indicated that using the ADDIE model in educational media development can produce products that are not only aligned with learning needs but also enhance student engagement and motivation.

### *Population, Sample, and Data Collection*

This study involved undergraduate students enrolled in geometry courses at several universities in Indonesia as the target population. The total estimated population consisted of approximately 300 students enrolled in mathematics education programs across selected higher education institutions. From this population, a sample of 60 students was selected using purposive sampling. This non-probability sampling method was employed to ensure that participants had prior experience with geometry coursework and demonstrated willingness to participate in the study. The sampling criteria were based on the assumption that students with such backgrounds were well-positioned to provide relevant feedback regarding the effectiveness of the developed Augmented Reality (AR)-based learning media.

Data for the study were collected using two primary instruments: a validation sheet and an effectiveness test. The validation sheet was used to assess the feasibility and quality of the AR-based learning media, covering dimensions such as content accuracy, instructional design, and user interactivity. Meanwhile, the effectiveness test aimed to measure improvements in students' conceptual understanding and learning interest after the use of the AR media in instructional settings.

To ensure the quality and credibility of the data collection instruments, both validity and reliability tests were conducted. The content validity of the validation sheet was established through expert judgment, with each expert evaluating whether the instrument accurately assessed the intended constructs—namely, the pedagogical soundness and instructional appropriateness of the AR media for geometry learning. The content validity was quantified using the Content Validity Index (CVI), where a CVI value above 0.80 was considered indicative of strong validity (Wang, 2015). Reliability was examined through the calculation of Cronbach's Alpha, with values exceeding 0.70 interpreted as acceptable levels of internal consistency (George & Mallery, 2016).

### *Data Sources and Sampling Procedure*

The primary data source for this study comprised students who participated in the classroom trial of the AR-based learning media during geometry instruction. A purposive sampling technique was employed, wherein participants were selected based on predetermined criteria aligned with the study objectives. A total of 60 students were included in the sample, with consideration given to their academic background in mathematics and their willingness to complete all stages of the research procedure.

### *Data Analysis*

The data collected were analyzed using paired sample t-tests to examine the mean differences in students' conceptual understanding and learning interest before and after the implementation of the AR learning media. The paired sample t-test was deemed appropriate for this study as it allows for the comparison of two related groups—specifically, the same set of students measured at two different time points (pre-test and post-test). This statistical procedure enables the researcher to determine whether the use of AR media produced statistically significant improvements in the targeted learning outcomes.

## RESULT AND DISCUSSION

This study aims to develop and test the effectiveness of Augmented Reality (AR)-based learning media to enhance students' conceptual understanding and learning interest in geometry courses. The results of this study are presented in several sections, including the validation test results, media effectiveness test results, and data analysis following the implementation of the AR media in the learning process.

### *Needs Analysis Results*

In the analysis phase, the researcher identified two main issues faced by students in geometry learning: low conceptual understanding and low learning interest. Based on the needs analysis and student characteristics, the researcher formulated the objectives for developing AR-based learning media to address these issues. The results of the analysis are presented in the table below:

**Table 1**. Results of Needs Analysis

| Identified Issues | Needs Analysis | AR Media Development Objectives |
|---|---|---|
| Low conceptual understanding of geometry | - Students struggle to understand abstract geometry concepts. | - Develop learning media that presents geometry concepts visually and interactively to facilitate understanding. |
| Low student interest in learning geometry | - Students find geometry boring and difficult to comprehend. | - Develop engaging and enjoyable learning media using AR technology to increase student engagement and motivation. |
| Limited existing learning media | - Existing media is limited to textual and 2D image-based content. | - Provide AR-based media that enables interactive learning and offers a more immersive educational experience. |
| Lack of visual reinforcement in learning | - Students need visual support to understand spatial and geometric concepts. | - Develop AR models to display 3D geometric objects, enabling students to interact directly with them. |

### *AR Media Design Results*

During the design phase, the researcher developed AR-based learning media aimed at enhancing students' conceptual understanding and learning interest in geometry. This AR media was designed with interactive features that allowed students to engage directly with three-dimensional geometric objects such as triangles, cubes, and spheres through mobile devices. The user interface was designed to be simple and intuitive, with a main menu allowing students to select geometry topics, manipulate 3D objects, and access interactive guidance. In addition, the media featured animations illustrating geometric transformations, practice exercises, and interactive quizzes to assess students' understanding. Real-time feedback was provided to give immediate responses to students' interactions with the objects, supporting the learning process effectively. The development of detailed 3D models aimed to provide a clear representation of the shapes and properties of the geometric objects being studied, facilitating a deeper understanding of the concepts. The design sought to create an engaging and interactive learning experience that would increase student involvement and motivation in geometry learning.


**Figure 2.** AR Geometry Media Interface

***Validation Test Results***

The validation of the AR learning media was conducted by three experts: a mathematics content expert, a learning media expert, and an AR technology expert. The validation aimed to assess the feasibility and quality of the developed AR media based on various criteria, such as content relevance, design, interactivity, and usability. Each expert evaluated the AR media's suitability using a Likert scale, ranging from 1 (not feasible) to 5 (very feasible).

**Table 2.** AR Media Validation Test Results

| Evaluated Aspects | Expert 1 Rating | Expert 2 Rating | Expert 3 Rating | Average Score | Remarks |
|---|---|---|---|---|---|
| Content Relevance | 4.2 | 4.4 | 4.3 | 4.3 | Very Feasible |
| Ease of Use | 4.5 | 4.7 | 4.4 | 4.5 | Very Feasible |
| Visual Design and Interactivity | 4.0 | 4.1 | 4.2 | 4.1 | Feasible |
| Alignment with Learning Objectives | 4.3 | 4.5 | 4.4 | 4.4 | Very Feasible |
| AR Technology Quality | 4.1 | 4.3 | 4.2 | 4.2 | Feasible |

Based on the validation results, the developed AR learning media received an average validity score of 4.2, indicating that it is highly feasible. The highest ratings were given for ease of use (4.5) and content relevance to the geometry curriculum (4.3). These results suggest that the developed media is not only relevant to the learning objectives but also user-friendly, in line with effective instructional design principles (Kurniawan et al., 2020).

***AR Media Effectiveness Test Results***

After the validation phase, the AR media was implemented in geometry learning with 60 students as the research sample. The effectiveness test was conducted using two main instruments: a conceptual understanding test in geometry and a learning interest questionnaire. The conceptual understanding test consisted of 20 multiple-choice questions that assessed students' understanding of fundamental geometry concepts, such as plane figures, solids, and geometric transformations. The learning interest questionnaire included 15 items measuring changes in students' interest in studying geometry after using the AR media.

**Table 3.** AR Media Effectiveness Test Results

| Variable | Before Using AR Media | After Using AR Media | T-value | P-value |
|---|---|---|---|---|
| Conceptual Understanding of Geometry | 60.3 (SD = 12.5) | 85.6 (SD = 9.7) | 15.23 | 0.000 |
| Learning Interest | 3.1 (SD = 0.8) | 4.2 (SD = 0.6) | 12.76 | 0.000 |

*Conceptual Understanding of Geometry*

Before using the AR media, the average score on the conceptual understanding test was 60.3 (out of 100), indicating relatively low comprehension. However, after using the AR media, the average score increased to 85.6, showing a significant improvement. Statistical analysis using the paired sample t-test revealed a significant difference between the pre- and post-test scores ($t = 15.23$, $p < 0.05$). This result indicates that the use of AR media significantly enhanced students' understanding of geometric concepts.

*Learning Interest*

According to the learning interest questionnaire, students' average score before using the AR media was 3.1 on a 5-point scale (indicating low interest). After using the AR media, their average score increased to 4.2, reflecting a significant increase in learning interest. The paired sample t-test also showed a significant difference in learning interest scores ($t = 12.76$, $p < 0.05$). This increase in learning interest suggests that the AR media not only improved conceptual understanding but also successfully engaged students, making the previously perceived boring and difficult subject of geometry more interesting and enjoyable.

***Results of Limited Trials and Implementation***

After the AR-based learning media was tested in a limited trial involving 60 students, the majority of students provided positive feedback regarding its use in the learning process. Approximately 85% of the students stated that the AR media helped them understand geometric concepts more easily, while 80% reported feeling more interested and motivated to learn geometry after using the media. These findings suggest that the use of AR technology in geometry education has a positive impact on students' understanding and learning interest, aligning with previous studies highlighting the potential of AR in education (Hamid et al., 2021; Kurniawan et al., 2020).

**Table 4.** Results of Limited Trials and Implementation

| Aspect Evaluated | Percentage of Students (%) | Description |
|---|---|---|
| Ease of Use | 85% | AR media is easy for students to use. |
| Improvement in Concept Understanding | 90% | The majority of students found it easier to understand geometric concepts. |
| Learning Interest | 80% | Students were more interested and motivated after using AR media. |
| Sustainability of Use | 70% | Students are willing to continue using AR media for further learning. |

Based on the results of the validation tests, effectiveness evaluation, and student feedback, it can be concluded that the AR-based learning media developed is effective in enhancing students' understanding of concepts and their interest in learning geometry. These findings suggest that AR technology can be a powerful tool in facilitating more interactive and engaging learning experiences, thereby improving student involvement and motivation. Therefore, the use of AR media in geometry education holds significant potential for wider adoption across educational institutions.

## *Discussion*

*Improvement in Geometry Concept Understanding*

One of the key findings of this study is the significant improvement in students' understanding of geometry concepts after using AR-based learning media. Before the use of AR media, the average score for concept understanding was 60.3, which increased to 85.6 after the use of the AR media, with a significant difference as indicated by the paired sample t-test ($t = 15.23$, $p < 0.05$). These results align with previous studies that demonstrate the potential of AR technology to enhance concept understanding across various disciplines, including mathematics. For example, the study by Hamid et al. (2021) developed AR-based learning media for geometry and found that AR use significantly improved students' understanding of concepts. Similarly, Kurniawan et al. (2020) found significant improvement in students' understanding of mathematics concepts when using AR media at the middle school level.

This study also confirms broader findings in the literature on the application of AR in education. Huang et al. (2016) discovered that AR helps students understand abstract concepts more concretely, thanks to the interactive visualizations provided by the technology. By providing dynamic and interactive geometric visualizations, AR enables students to better grasp challenging concepts such as geometric transformations and spatial relationships between objects.

The improvement in understanding can be attributed to the nature of AR, which provides a more engaging and interactive learning experience, thereby enhancing students' involvement in the learning process. This is consistent with constructivist learning theory, which emphasizes the importance of direct experience in learning (Piaget, 1973). With AR media, students not only passively receive information but also interact directly with geometric objects, thereby improving their understanding of the material.

*Enhancement of Student Interest in Learning*

In addition to improving concept understanding, this study also found that the use of AR media significantly increased students' interest in learning geometry. Before the use of AR, the average interest score was 3.1, and after using the AR media, the interest score increased to 4.2. Statistical analysis through the paired sample t-test revealed a significant difference in the interest scores ($t = 12.76$, $p < 0.05$).

These findings support previous research indicating that the use of technologies such as AR can significantly enhance students' interest in learning. Wu et al. (2013) developed AR for mathematics learning at the elementary school level and found that its use significantly increased students' interest in mathematics. Students who used AR media showed more engagement and motivation to learn compared to those who used traditional learning methods. Similarly, Nouri et al. (2019) asserted that AR can create a more engaging learning experience, which in turn increases students' interest in the subject.

The increase in interest can also be explained by Deci and Ryan's (1985) intrinsic-extrinsic motivation theory. The use of AR technology in learning provides a more enjoyable and engaging experience, which enhances students' intrinsic motivation. This enjoyable and interactive experience makes students feel more involved and motivated to continue learning. Additionally, AR technology provides students with the opportunity to learn in a more visual and hands-on manner. This is in line with Mayer's (2005) multimedia learning theory, which suggests that learning materials presented visually in an engaging and interactive way can improve students' attention and interest, thereby enhancing their learning process. In this context, AR media offers students the opportunity to explore geometric concepts in a more interactive and realistic environment, which helps reduce boredom and increases their interest in studying previously difficult-to-understand material.

*Comparison with Previous Research*

When compared to previous studies, the results of this research reveal similar findings in terms of the effectiveness of AR in geometry education. However, this study also offers new contributions, particularly in the context of higher education in Indonesia. Many previous studies, such as those by Hamid et al. (2021) and Kurniawan et al. (2020), focused on primary and

secondary education, while this study explores the application of AR at the higher education level, specifically in the subject of geometry, which is a relatively more complex topic requiring deeper understanding. Furthermore, this research confirms the findings reported by Zhou et al. (2020) in the context of AR use in mathematics education. They found that the use of AR in mathematics learning improves students' understanding, especially in geometry, which is often perceived as difficult and abstract. This study also supports the results of Al-Mousa et al. (2019), who stated that AR can enhance learning effectiveness by providing visual and interactive experiences that are difficult to achieve through traditional methods.

In the context of education in Indonesia, these findings are also relevant to research by Indriani et al. (2020), which showed that the use of technology in education, especially AR, can improve students' interest in subjects considered difficult. This study provides empirical evidence that AR can be implemented in higher education to improve the quality of learning and help students overcome challenges associated with complex subjects such as geometry.

*Implications for the Development of Mathematics Learning in Higher Education*

The results of this study have important implications for the development of mathematics education at the higher education level. The use of AR in geometry learning not only improves concept understanding but also stimulates students' interest in learning. Therefore, the use of technologies such as AR should be considered as part of an innovative teaching strategy in subjects involving abstract and complex concepts like geometry. However, despite the promising results of this study, the implementation of AR technology requires adequate resources, including supporting hardware and software, as well as training for both faculty and students to maximize the potential of this technology. Further research involving larger sample sizes and various disciplines is also needed to explore the broader potential of AR in educational contexts.

## CONCLUSION

The conclusion of this study indicates that the development of Augmented Reality (AR)-based learning media can significantly improve students' understanding of geometry concepts and their interest in learning the subject. Based on validation tests, the developed AR media received a favorable evaluation from experts, with an average score of 4.2. Furthermore, the effectiveness test results showed a significant improvement in students' concept understanding and learning interest after using the AR media, with a very low p-value ($p < 0.05$). These findings are consistent with the results of various previous studies, which also demonstrated the success of using AR in mathematics and science education. Therefore, AR-based learning media can be considered an effective alternative to enhance the quality of geometry education in higher education and can be applied in other learning contexts to increase student engagement and motivation.

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