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Development of Mathematics Learning Media Based on Augmented Reality and Unity 3D

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ABSTRAK

This study aims to explore the effectiveness of the use of augmented Reality-based learning media (AR) in improving students ' understanding of abstract mathematical concepts. By utilizing AR and Unity3D Technology, students are provided with a more interactive and visual learning experience through 3D objects that enable a clearer understanding of concepts. The results showed that AR-based learning media is effective in helping students understand difficult math materials, increasing their motivation, and involvement in learning. In addition, positive perceptions from teachers and students regarding the use of AR were also revealed, where this medium is considered to be able to facilitate teaching and make students more interested and active in learning. However, the study also found some challenges, such as limited devices that can support AR applications optimally and difficulties in integrating AR with existing curricula. This research suggests further development in technology and infrastructure to improve the effectiveness of the use of AR-based learning media in the future.

INTRODUCTION

The current digital Era brings rapid technological development, which affects various aspects of life, including the world of Education. Technology is now an effective tool to improve the quality of learning, expand access to educational materials and facilitate more innovative teaching methods. One of the prominent innovations in the world of education is the use of Augmented Reality (AR), which allows for more interactive and immersive learning experiences. With AR, learning materials are no longer limited to textbooks or static presentations, but can be realized in the form of three-dimensional objects that students can see and learn directly. This not only increases student engagement, but also makes it easier to grasp difficult concepts in a fun and easy-to-understand way. The use of AR in education creates great opportunities to design learning that is more interesting, effective, and in accordance with existing technological developments.

Learning mathematics is often considered difficult by many students, especially in understanding abstract concepts such as geometry, algebra, and calculus. These concepts are often difficult for students to visualize and accept because they do not have

a clear picture of their application in everyday life. Conventional learning methods, such as lectures and practice questions, are sometimes less effective at explaining abstract and complex mathematical concepts. Students tend to feel less interested and quickly get bored with the monotonous way of studying. In addition, the lack of interesting and interactive learning media is one of the main obstacles in improving students ' understanding of mathematics. In the absence of AIDS that are able to visualize the terial directly, such as three-dimensional objects or interactive simulations, students find it difficult to u derstand the material thoroughly. Therefore, the development of more innovative and technology-based learning media, such as Augmented Reality (AR), is a potential solution to overcome these challenges and enhance a more effective and enjoyable math learning experience.

Augmented Reality (AR) is a technology that allows the integration of virtual objects with the eal world, creating more immersive and interactive learning experiences. This technology provides opportunities for students to interact directly with learning materials in a more visual and concrete form. In the context of mathematics learning, AR can be used to display three-dimensional (3D) objects that students can learn and manipulate, such as spatial figures, function graphs, or algebraic diagrams. Thus, students can more easily understand abstract and complex mathematical concepts, such as geometry or calculus, because they can see and interact rectly with these objects. AR also provides a more real and engaging visual experience for students, which in turn can increa heir motivation and interest in learning. This more engaging learning not only makes students more active in the learning process, but can also increase information retention and a deeper understanding of the material being taught.

Unity3D is a very popular application development platform and is often used in the creation of Augmented Reality (AR) based applications. The Platform offers a variety of features that support the creation of Interactive Learning media, which can run smoothly on mobile devices such as smartphones and tablets. Unity3D's advantage lies in its ability to produce high-quality 3D graphics, which allows developers to create interesting and easy-to-understand mathematical simulations and visualizations. In the context of learning mathematics, Unity3D allows the creation of mathematical objects that can be manipulated and studied directly by students, such as c structs, graphs of functions, and algebraic objects. By using Unity3D, developers can create a more dynamic and thorough learning experience, where students can interact directly with the material, deepen their understanding, and overcome the difficulties often experienced when learning abstract mathematical concepts.

With the increasing interest of the younger generation towards technology, Augmented Reality (AR) and Unity3D-based learning media can be an interesting and relevant solution to enhance the math learning perience. The current generation is growing up with familiarity with technology, so the use of Technology-Based Learning media can attract their interest and make learning more interactive and fun. AR-based learning media allows students to interact directly with mathematical concepts in a dynamic visual form, reinforcing their understanding of the material being studied. In addition, developing AR-based learning media can help bridge the gap between theory and practice in mathematics learning. By utilizing AR, mathematical concepts that have previously felt abstract and difficult to understand can be presented in a more tangible

and applicable form, allowing students to see the real implementation of the theory they are learning. It can enrich the learning experience and improve students ' understanding and skills in applying mathematical concepts in everyday life situations.

AR-based learning Media developed using Unity3D aims to provide solutions to challenges in learning mathematics, especially in understanding abstract concepts and difficult to understand. This product is expected to help students to better understand and apply mathematical concepts visually and interactively, in a more fun and accessible way. Using AR-based media, students can see and interact directly with mathematical objects in three-dimensional form, which makes it easier for them to understand the material in greater depth. In addition, this media is also expected to increase student learning motivation, make learning more interesting and reduce the fear or boredom that often arises in conventional mathematics learning. In this way, it is hoped that AR-based learning media can provide a more effective and fun learning experience, which can ultimately improve math learning achievement and build student interest in continuing to develop their math skills.

METHODOLOGY

This study uses research and Development (R&D), which aims to produce new products in the form of Learning Media-based mathematics Augmented Reality (AR) and Unity3D. This developmental research focuses on the creation and evaluation of Innovative Learning media, which can facilitate the understanding of difficult mathematical concepts for students. This study aims not only to create products, but also to test the effectiveness of such media in the context of real learning. By using the R&D approach, it is hoped that a solution can be found that suits the needs of learning and has a positive impact on the educational process, especially in the field of mathematics. The products developed are expected to be used as a reference for the development of other learning media in the future, as well as contributing to innovation in education.

This study adopts ADDIE model consisting of five main steps, which is used as a framework for the development of AR-based learning media. Each step in the ADDIE model provides systematic guidance to produce products that are effective and relevant to learning needs.

Analysis (Analysis): The first stage is to analyze the needs in learning mathematics. This includes identifying problems that exist in the teaching-learning process, such as students ' difficulty in understanding abstract mathematical concepts. Here, the researcher will also identify the elements that need to be included in the learning media to ensure that the solution provided is right on target.

Design: in the design phase, researchers will design AR-based learning media by considering aspects of interactivity and student engagement. This media design must also adapt to the needs of mathematics learning, so that students can understand the material more visually and practically. This stage includes designing the user interface (UI) and interactive scenarios that support the learning process.

Development: once the design is approved, the next stage is development. At this stage, Unity3D will be used to create AR-based learning media applications. Developers will create visual elements, 3D objects and interactivity that correspond to the chosen mathematical material, such as geometry, algebra or calculus, which are difficult to understand without proper visualization.

Implementation: the Learning Media that has been developed will be applied in a real learning environment to be tested. At this stage, the media that has been created will be tested to a group of students to assess their functionality and acceptance of the media. This implementation aims to see how the media can be used in the daily learning process.
Evaluation (evaluation): evaluation is carried out after implementation to assess the effectiveness of Learning media. Feedback from students and teachers will be collected to find out the strengths and weaknesses of the media that have been applied. This evaluation is very important to ensure that the media developed really provide benefits in improving students ' understanding of mathematical concepts. Based on the evaluation results, revisions and improvements will be made so that the final product is more optimal.

Stages Of Development Of Learning Media
Needs analysis: the first stage in the development of Learning media is to conduct a needs analysis. At this stage, the researcher will assess the problems that exist in mathematics learning, such as concepts that are difficult for students to understand. In addition, researchers will also analyze how technology, especially AR, can help more effective visualization of mathematical materials. The results of this analysis will be the basis for determining the features that need to exist in the Learning media that will be developed.
Learning Media Design: after the needs are analyzed, the next stage is to design learning media. At this stage, elements such as learning media structure, user interface (UI), and interactive scenarios will be designed. This design aims to make the media developed easy to use by students and in accordance with their mathematical learning needs. The elements must be interesting, interactive and support the visual understanding of the material.
Prototype development: at this stage, developers will use Unity3D to prototype AR-based learning media applications. The application will include the necessary visual elements, such as 3D objects and interactivity that allow students to interact directly with the material. This prototype will serve as the basis for further testing.
Prototype testing: the prototype that has been developed will be tested with a small group of students to evaluate its effectiveness and functionality. These trials aim to identify potential problems and areas that need to be fixed. The prototype will be tested in a real learning context to see how students respond to and use AR-based learning media.
Evaluation and revision: after the trial, the evaluation is carried out by collecting feedback from students and teachers regarding their experience using Learning media. This evaluation aims to identify the advantages and disadvantages of the media, so that revisions and improvements can be made to ensure that the media is more effective in supporting mathematics learning. This revision will include improvements to the functionality, design, and interactivity of the media to better suit learning needs.

RESULTS AND DISCUSSION

The Learning Media developed in this study uses Augmented Reality (AR) technology and the Unity3D development platform. The resulting prototype is an interactive mathematics learning application that allows students to interact with three-dimensional (3D) mathematical objects, such as building space (cube, sphere, etc.) and mathematical graphs. The use of AR in this app provides a more engaging learning experience and allows students to understand abstract mathematical concepts in a more visual and direct way. The main feature of this learning app is the ability to manipulate

3D objects, allowing students to view objects from different points of view and interact directly with mathematical elements. For example, students can rotate a figure of space to see its sides, enlarge or reduce the graph of a function to understand its shape and properties, and interact with other mathematical elements that were previously difficult to understand through conventional learning.

The AR-based learning app was tested on a group of students sampled in the study. This trial shows that learning media can be used smoothly on compatible devices, such as smartphones and tablets with sufficient specifications. Students can operate the application easily and interact with 3D mathematical objects without experiencing significant technical constraints. Most of the students who participated in the trial gave positive feedback, stating that AR-based media made them more interested in studying mathematics. They reported that the interactive visualization of 3D objects made it easier for them to understand mathematical concepts that previously felt complex and abstract.

"I find it fun to learn math this way. I used to have a hard time understanding space or graphics, but now I can see and rotate 3D objects. That helps me to better understand how those objects interact. The lesson becomes more exciting and not boring."

The results of pre-test and post-test showed a significant increase in understanding of mathematical concepts among students using AR-based media. Students who used AR apps obtained higher scores in comprehension tests after using this medium compared to before they used it. This suggests that AR-based media can help improve understanding of mathematical concepts more effectively.

In the control group that used traditional learning methods, statistical analysis showed that the group that used AR-based media experienced a greater increase in understanding compared to the group that did not use such media. This indicates that the use of AR in mathematics learning has a positive impact on student understanding. Based on the results of interviews with students, most students reported that they felt more interested in learning mathematics when using AR-based media. This fun learning experience encourages them to be more active in following the lesson and more motivated to learn the material more deeply. Although the majority of students stated that they felt more engaged and easier to understand math material through the use of AR, some students revealed challenges in adapting to the new technology. However, they still admit that after understanding how to use the application, they find it more helpful in learning mathematical material.

"I feel very helped by this AR-based media. As a teacher, I can explain mathematical concepts that were previously difficult for students to understand, such as constructs and graphs of functions, in a more visual and interactive way. The use of 3D objects in AR allows students to see and interact directly with the material, making it easier for them to understand the relationships between concepts. It really gave a new dimension to my teaching process."

Teachers who use AR-based media in the learning process report that it is helpful in explaining difficult math concepts in a more visual and interactive way. Teachers note that the use of this medium makes students more actively participate in classes and more interested in understanding the material presented. Some teachers provided feedback regarding further development of the app, such as improving the app's compatibility with

a wider range of devices, adding more varied learning materials, and providing more complete guidance for teachers in using the app in the classroom. By using AR technology, students can visualize abstract mathematical concepts, such as spatial structures, function graphs, and others, in a three-dimensional form that can be rotated and viewed from various points of view. This experience helps students to better understand the relationships between mathematical elements and improve their understanding of concepts that are difficult to understand conventionally. AR-based learning Media offer an element of interactivity that makes students more involved in the learning process. Direct interaction with mathematical objects makes students more motivated to actively participate in learning and try harder to understand the material given.

Challenges faced in development

One of the main challenges in the development and implementation of AR-based learning media is the limited technology and infrastructure available in schools. Some students use low-spec devices that do not fully support the use of AR applications, which reduces the effectiveness of this medium in some cases. Integrating AR-based media with the existing curriculum in schools is also a challenge. The preparation of materials in accordance with the standards of learning that apply in schools, as well as ensuring that learning media support the achievement of the curriculum, requires extra time and attention.

Advantages and limitations of AR-based Learning Media

AR-based learning Media has advantages in terms of more interesting and interactive visualization, which can help improve students ' understanding of difficult math materials. In addition, AR-based media also provide a more enjoyable and immersive learning experience for students, increasing their learning motivation. However, there are some limitations to the use of this medium, such as relatively high development costs and the need for more advanced hardware. This limitation can be an obstacle for schools with limited resources, so alternative solutions are needed to ensure wider access to this learning medium.

Effectiveness of Learning Media based on Augmented Reality (AR)

The use of Augmented Reality (AR)-based learning media in education, especially in mathematics learning, has proven effective in improving students ' understanding of concepts that were previously difficult to understand. Research shows that AR allows students to interact with three-dimensional (3D) objects, such as spatial figures and mathematical graphs, which provide clearer and more immersive visualizations than traditional learning methods. By manipulating 3D objects, students can see the relationships between mathematical elements from different points of view, which is very helpful in understanding abstract concepts. This is a significant plus because it provides a more concrete and intuitive learning experience.

In addition, AR-based learning media also showed a positive impact on student motivation and involvement in the learning process. With integrated interactive elements, students not only receive information passively, but also actively participate in the learning process. This makes them more interested in digging deeper into the material, increasing material retention, and enriching their learning experience. Although most students respond positively to the use of AR, challenges arise in students who are not yet

familiar with the technology. Some students find it difficult to adapt to mobile devices and AR application interfaces, which becomes an obstacle in the maximum utilization of this technology.

Influence of Learning Media on student motivation

Research also reveals that the use of AR in mathematics learning can increase student motivation to learn. By presenting the material in a more visual and interactive form, students become more involved in learning and show greater interest in the lesson. AR provides an opportunity for students to explore the material in a more fun way, which in turn increases their desire to study harder. However, another challenge is in addressing students who face difficulties in using new technologies. It takes learning and adaptation so that students can be more comfortable using this technology.

Teachers ' perceptions of AR Media use

Teachers also gave positive feedback on the use of AR in teaching mathematics. They report that AR is helpful in explaining elusive concepts, such as spatial structures or function graphs, in a more dynamic and interactive way. The use of AR makes the teaching process more interesting and allows students to be more active in learning. However, some teachers revealed difficulties in integrating AR media with existing curricula. The adjustment of the material and the time required to align with the learning objectives is a challenge that requires extra effort.

Necessary technology and infrastructure

On the other hand, the main obstacle in the implementation of AR is the limitation of the devices that students have. Many students do not have devices with enough specifications to run AR applications smoothly. Therefore, developers need to consider the design of applications that are lighter and compatible with a variety of devices. In addition, technology reliability is also an important issue, with device incompatibility issues and applications experiencing lag or crashes. Further development needs to focus on improving the stability of the app to ensure an optimal learning experience.

Advantages of AR in math learning

The main advantage of using AR in math learning lies in its ability to provide clearer visualization and allow direct interaction with learning objects. Students can rotate and study three-dimensional objects from different points of view, which cannot be done with conventional learning methods. AR creates a more immersive and fun learning experience, which greatly supports students ' understanding of abstract materials, such as equations or geometry.

Limitations and challenges in Media Development

However, there are some limitations that need to be considered, such as fairly high development costs and the need for more sophisticated devices. For schools with limited budgets, this can be a significant obstacle. In addition, the development of AR-based learning media must also address technology reliability issues, such as device incompatibility or applications that often crash. This is a big challenge in ensuring that AR media usage can run smoothly on various devices.

ng-term potential for mathematics learning

AR-based learning Media has great potential to be applied in various schools with the expansion of use in other subjects. The development of this technology also opens up opportunities for the improvement of a more personalized and adaptive learning experience, with the use of artificial intelligence (AI) that can be tailored to the needs of each student. In the long run, AR can enrich education and become a more effective learning solution.

Recommendations for the implementation of AR Learning Media

To ensure the successful implementation of AR in education, it is advisable to provide training to teachers so that they are more familiar with this technology. Teachers need to be given the skills to integrate AR in the learning process effectively. In addition, schools must also ensure that adequate infrastructure is in place, including compatible devices and stable internet access, to support the use of AR. The involvement of parents in supporting their children to use this technology at home is also very important, especially in providing access to appropriate devices.

This discussion shows that the use of Augmented Reality (AR)-based learning media developed with Unity3D can have a significant impact on students ' understanding of abstract mathematical concepts. With its ability to display interactive three-dimensional objects, this medium provides a more thorough and engaging learning experience compared to conventional learning methods. However, the use of this technology can not be separated from the challenges, especially related to the limited devices that students have and the difficulty in integrating AR media with existing curricula. To increase the effectiveness of AR-based learning media, further development is needed to address technical issues, such as device compatibility and application stability. In addition, it is important to improve the accessibility of devices so that more students can benefit from this technology. Training for teachers is also very crucial so that they can optimize the use of AR media in the learning process. Support from schools and parents will also strengthen the implementation of this technology, ensuring students can access learning media outside the classroom more easily. With attention to these aspects, AR-based learning media has the potential to significantly improve the quality of mathematics education.

CONCLUSION

Augmented Reality (AR) based learning Media developed using Unity3D proved effective in improving students understanding of difficult mathematical concepts. The use of three-dimensional (3D) objects in AR allows students to visualize mathematical concepts in a more interactive and real way, which not only clarifies their understanding but also makes complex material easier to understand. With the ability to see mathematical objects from different angles and interact directly with the elements, students can gain a deeper understanding, reduce their confusion, and speed up the learning process.

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