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DGMATH Berbasis Augmented Reality Sebagai Inovasi Media Pembelajaran di Era Digital

Dwi Ariani Finda Yuniarti[1], Fajar Abadi[2], Mochamad Syahrul Munir[3], Anwar Fu'adi[4], Bagus Hikmahwan[2]
[1,2,3,4,5] Akademi Komunitas Negeri Pacitan, Indonesia
E-mail: finda@aknpacitan.ac.id[1], fajar@aknpacitan.ac.id[2], syahrul@aknpacitan.ac.id[3], anwar@aknpacitan.ac.id[4], bagus@aknpacitan.ac.id[5]

Abstrak

Penggunaan media berbasis teknologi dapat mendukung kreativitas siswa serta dapat mengoptimalkan hasil belajarnya, terutama pada mata pelajaran matematika, dimana siswanya sering mengalami kesulitan. DGMATH AR merupakan media pembelajaran matematika berbasis teknologi Augmented Reality (AR) untuk membawa animasi dunia maya ke dunia nyata sesuai dengan materinya. Penelitian ini bertujuan merancang media pembelajaran berbasis AR dalam bentuk prototype 3D book berbasis AR. Materi yang digunakan adalah sifat-sifat bangun ruang untuk siswa kelas 2 Sekolah Dasar (SD). Penelitian ini merupakan penelitian deskriptif kuantitatif dengan subjek penelitian adalah pengguna media pembelajaran yaitu guru, siswa dan orang tua. Metode yang digunakan adalah metode Multimedia Development Life Cycle (MDLC) dengan 6 tahapan yaitu concept, design, material collecting, assembly, testing dan distribution. Instrumen yang digunakan berupa kuesioner yang merujuk pada USE Questionnaire dengan jumlah 30 butir pernyataan yang dikelompokkan dalam 4 dimensi yaitu daya guna (*usefullnes*), kemudahan penggunaan (*ease of use*), kemudahan dipelajari (*ease of learning*), kepuasan (*satisfaction*) dan kuesioner tersebut diberikan kepada 100 orang responden. Hasil pengujian USE Questionnaire diperoleh 81,12% untuk indikator *usefullnes*; 82,25% untuk *ease of use*; 82,31% untuk *ease of learning* dan 80,11% untuk *satisfaction*. Sehingga dapat disimpulkan bahwa DGMATH berbasis AR ini sangat layak digunakan sebagai media pembelajaran matematika di era digital.

Kata Kunci: augmented reality, DGMATH, digital native, inovasi, pembelajaran era digital

DGMATH-based Augmented Reality as Learning Media Innovation in the Digital Era

Abstract

The use of technology-based media can support students' creativity and optimize their learning outcomes, especially in mathematics, where many students often face difficulties. DGMATH AR is an augmented reality (AR)--based mathematics learning media designed to bring virtual animations into the real world in alignment with the learning material. This study aims to design AR-based learning media. The material used focuses on the properties of solid shapes for second-grade elementary school students. This research is a quantitative descriptive study involving users of the learning media, including teachers, students, and parents, as the subjects. The method employed is the Multimedia Development Life Cycle (MDLC), which consists of six stages: concept, design, material collection, assembly, testing, and distribution. The instrument used was a questionnaire based on the USE Questionnaire, comprising 30 statements grouped into four dimensions: usefulness, ease of use, ease of learning, and satisfaction. The questionnaire was administered to 100 respondents. The results of the USE Questionnaire showed scores of 81.12% for usefulness, 82.25% for ease of use, 82.31% for ease of learning, and 80.11% for satisfaction. Thus, it can be concluded that the AR-based DGMATH is highly suitable for use as mathematics learning media in the digital era.

***Keywords**: augmented reality; DGMATH; digital era learning; digital native; innovation*

INTRODUCTION

Merdeka Curriculum aims to provide opportunities tailored to student's interests and aspirations (Mahlianurrahman & Aprilia, 2022). Its implementation is closely linked to the use of learning media, which serves as a critical tool for achieving learning objectives effectively (Masfufah et al., 2022). Properly selected learning media can assist students in understanding concepts or materials being taught (Narestuti, Sudiarti, & Nurjanah, 2021). This is particularly relevant for mathematics, a subject often viewed as a challenge by students who struggle to grasp its concepts. Thus, innovation in mathematics education is necessary. Today's students, known as digital natives, have been deeply familiar with technology since birth (Handayani & Fauzi, 2023). Consequently, teachers must adapt their methods and incorporate technology-based media in their teaching practices. However, a prevalent challenge is the limited digital proficiency among teachers (Rahma, Harjono, & Sulistyo, 2023), which hinders the effective use of technology-based learning media. Additionally, findings from the author's prior research on the Needs Analysis of Augmented Reality (AR)-Based Mathematics Learning Media revealed that teachers lack sufficient knowledge about AR, in line with the statement Tamur, Pantaleon, & Sennen (2024) Assisting in creating AR-based learning media. Despite this, teachers expressed a need for digital media that supports students' potential and interests in learning (Prasetya, Rivasintha, & Oktarika, 2023). Therefore, this study focuses on the problem of designing and analyzing AR-based mathematics learning media as an innovative solution for mathematics education in the digital era. Supported by research conducted by Gusteti et al. (2023) This also states that AR enriches the learning experience by increasing student engagement and understanding, especially in the visualization of complex concepts such as spatial geometry and function graphs.

Augmented reality (AR) is defined as a technology capable of merging the real world with the virtual world, operable on Android-based smartphones (Satyahadewi & Mutiah, 2019). AR has the potential to transform education into smart education (Fauziyyah, 2019), significantly changing the learning process not only as a technology-based medium but also as a tool for students to acquire knowledge, participate actively, and develop positive attitudes toward their learning. Over the past five years, the use of AR technology in education has grown significantly (Deda, Disnawati, & Missa, 2022), presenting a challenge for teachers to develop AR-based learning media.

Previous research has explored the use of AR-based mathematics learning media. For example, a study by Rusdi, Prasti, & Rais (2021) Aimed to design and develop an AR-based mathematics learning application for geometry topics. The results showed that the AR-based mathematics learning media developed was highly rated by students. The AR-based Problem-Based Learning (PBL) model has also been proven to improve students' mathematical problem-solving abilities (Mulianti, Susanta, Hanifah, & Haji, 2023). Another study by Syahid, Ardianto, & Arifin (2024) Developed AR-based learning media, demonstrating that AR-based learning is valid, practical, and effective for elementary students. Similarly, AR-based media has been shown to effectively enhance students' knowledge competence (Siti & Majid, 2024) And influence elementary students' critical thinking skills. Additionally, research by Irmayanti, Sri Andar Muni, & Pratiwi (2022) Indicated that AR-based media creates a more interactive learning environment for mathematics. Given these technological advancements, AR should be considered and further developed as a learning medium that supports educational activities in the digital era. The advantage provided in this study compared to previous studies is the packaging of AR-based learning media which is made more attractive to students, not just a barcode that appears but in the form of a two-dimensional visual image in the form of a book when scanned will display an explanation by the DIGI character related to the material on spatial shapes in three-dimensional visuals.

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Figure 1. Android-Based DGMATH Application

This study is an innovation building upon previous research related to the development of the Android-based learning media, DGMATH. DGMATH stands for "Digital Mathematics," and in prior research conducted by the authors in 2021, a mathematics learning media named DGMATH was developed. This Android-based application took the form of an educational game focusing on arithmetic operations for first-grade elementary school students (Yuniarti, Intyanto, & Pawening, 2022).

In the subsequent year, 2022, the research was further developed by integrating the Android-based DGMATH into the Project-Based Learning model. The findings of this study revealed that the implementation of Android-based DGMATH increased students' learning motivation and positively impacted their academic performance. It was also concluded that DGMATH is an effective learning media for use in the digital era (Prianggono & Yuniarti, 2023).

METHOD

This research is a quantitative descriptive study involving users of the learning media, including teachers, students, and parents, as the subjects. This study employs the Multimedia Development Life Cycle (MDLC) method, focusing solely on the design and prototyping (Makaborang & Talakua, 2023) Of an educational game based on AR. The MDLC method consists of six stages: concept, design, material collecting, assembly, testing, and distribution (Sari, Batubara, Hazidar, & Basri, 2022).

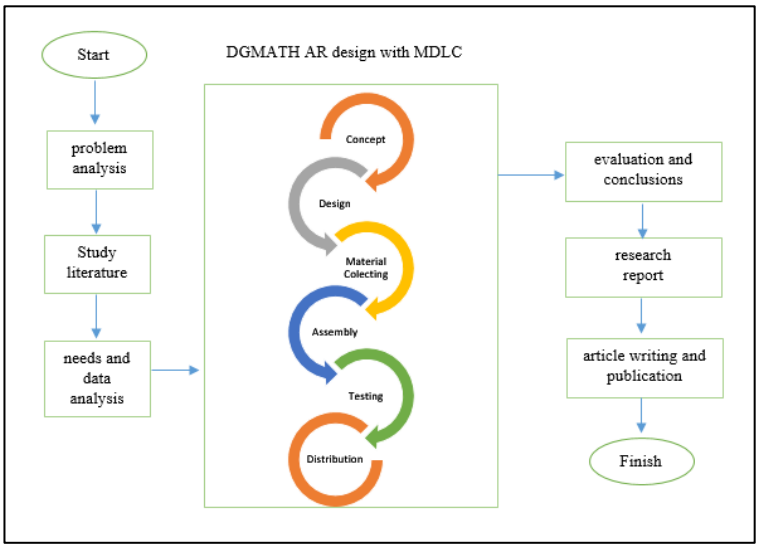

Figure 2. Research Methodology

The design of the AR-based DGMATH development method is (1) Concept, AR-based learning media in this study is designed as a prototype of a three-dimensional book featuring AR-based

material on geometric shapes for second-grade elementary school students. When the book is scanned using the AR-based DGMATH application, animated 3D visuals accompanied by voice explanations appear, transforming abstract mathematical concepts into more tangible representations. (2) The design, specifications, and appearance of the application are adapted and further developed based on the character designs and color combinations used in the previous version of the DGMATH application. (3) Material Collecting, this stage involves creating 3D models, rigging, animating, and compiling them into AR formats. (4) Assembly, all multimedia materials and objects for the application are created using various software tools, including Blender for 3D animations, Overly for Augmented Reality, and Adobe After Effects for application editing. The development of the application adheres to the predetermined design phase. (5) Testing, the application undergoes testing by distributing a questionnaire about the AR-based DGMATH application to 100 prospective users. (6) Distribution, at this stage, the completed application is stored in a suitable storage medium. The learning media is presented as a prototype of an AR-based 3D book that works with the AR-based DGMATH application, accessible via smartphone. The AR-based DGMATH Book prototype was tested on 100 respondents, comprising 60 students, 20 teachers, and 20 parents or guardians. The comparison of the number of respondents is based on the consideration that students are the primary users of the learning media, while teachers and parents act as learning companions at home, whose feedback and suggestions are also essential for the development of this learning media. The research instrument used the USE Questionnaire because the USE Questionnaire is an instrument commonly used in testing Augmented Reality-based media and consists of 30 questions divided into four dimensions (Purwinarko, Subagja, & Yanuarto, 2020), as shown in Table 1.

Table 1. Use Questionnaire

No	Question	Question	Item Number
1	usefulness	8 Question	1 – 8
2	ease of use	11 Question	9 – 19
3	ease of learning	4 Question	20 – 23
4	satisfaction	7 Question	24 – 30

For the usability analysis testing, data were analyzed using basic descriptive statistics. The usability testing was conducted following Equation (1).

$$Feasibility\ Percentage\ (\%) = \frac{Observed\ Score}{Expected\ Score} \times 100 \quad \ldots (1)$$

The Likert scale was used as the evaluation criterion, with four response options: Strongly Agree (SA) with a score of 4, Agree (A) with a score of 3, Disagree (D) with a score of 2, and Strongly Disagree (SD) with a score of 1. The results were then compared with the standard shown in Table 2 (Shanklin, Kortum, & Oswald, 2022).

Table 2. System Usability Categories

Number (%)	Category
81 – 100	Highly Feasible
61 – 80	Feasible
41 – 60	Less Feasible
21 – 40	Not Feasible
< 21	Highly Not Feasible

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RESULTS

Design of AR-Based DGMATH Product

This research produced a prototype book called the DGMATH Book based on Augmented Reality. The design process for the AR-based DGMATH Book began with storyboard and storytelling development. The book covers spatial geometry topics, including cubes, rectangular prisms, square pyramids, triangular prisms, cones, cylinders, and spheres. Below is the draft storyboard and storytelling developed for the AR-based DGMATH Book prototype. From this design, 3D animations were created and integrated with AR technology. The 3D assets include the character "DIGI" in 3D form and seven 3D geometric shapes. Figure 3 below illustrates the assets featured in the 3D animation of the AR-based DGMATH Book.

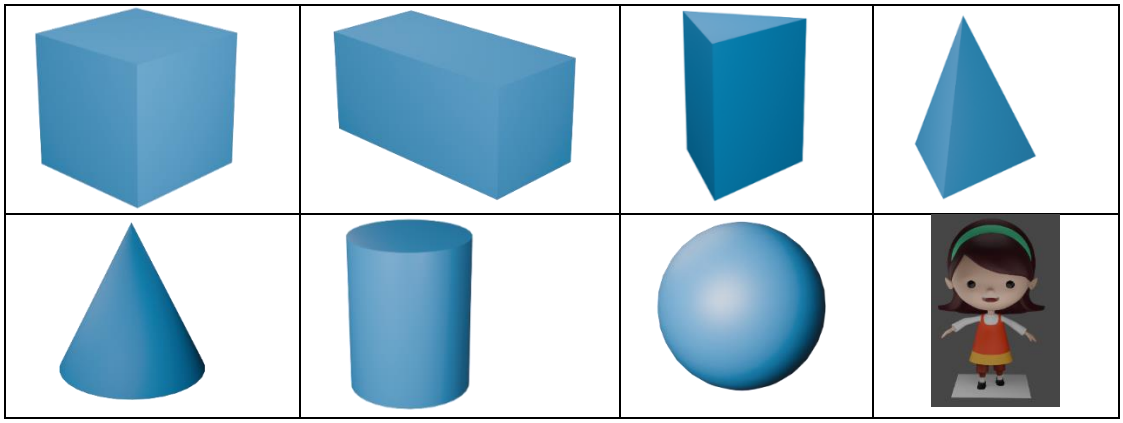

Figure 3. DIGI Character and 3D Geometric Shapes Assets

Each created asset was combined with voice-over (audio) explanations of the material. One of these processes, illustrated in Figure 4, was done using Blender software.

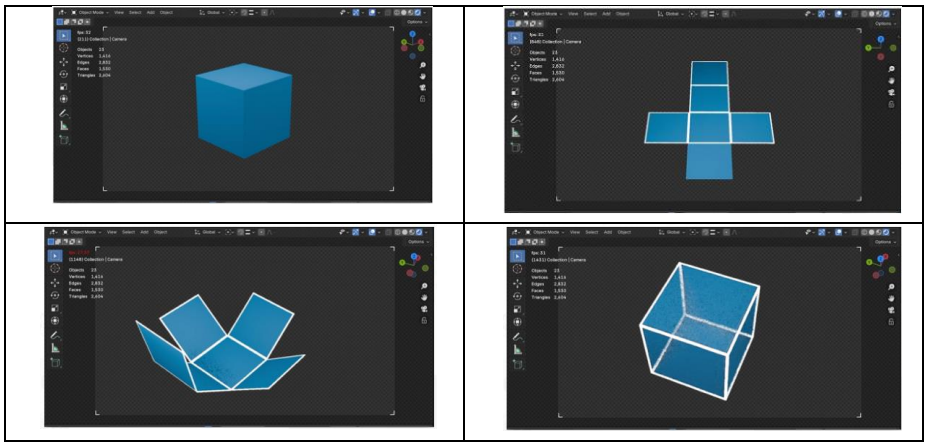

Figure 4. Animation Creation Using Blender Application

The AR-based DGMATH Book prototype design consists of eight pages, along with two cover pages (front and back). Page 1 introduces the character "DIGI," while pages 2 through 9 sequentially explain topics about cubes, rectangular prisms, square pyramids, triangular prisms, cones, cylinders, and spheres. The design created for the DGMATH Book prototype is as follows.

Figure 5. Layout Design of DGMATH Book

Data Analysis

The usability analysis was conducted with 100 respondents, including students, teachers, and parents/guardians. Below are the results of the system usability analysis for AR-based DGMATH. Based on Table 3, the recommended score is calculated as the total number of statements multiplied by the maximum score, and then multiplied by the number of respondents. The score obtained from respondents is calculated by multiplying the total number of statements by the number of respondents. The usability analysis percentage is determined by comparing the obtained score with the recommended score.

Table 3. Usability Analysis Results Using the USE Questionnaire

Assessed Aspect	Recommended Value	Obtained Value	Percentage
usefulness	3200	2596	81,12%
ease of use	4400	3619	82,25%
ease of learning	1600	1317	82,31%
satisfaction	2800	2243	80,11%

In product and service usability analysis, the USE Questionnaire is used, which comprises 30 statements grouped into four dimensions: usefulness, ease of use, ease of learning, and satisfaction (Jannah, Sobandi, & Suwatno, 2020).

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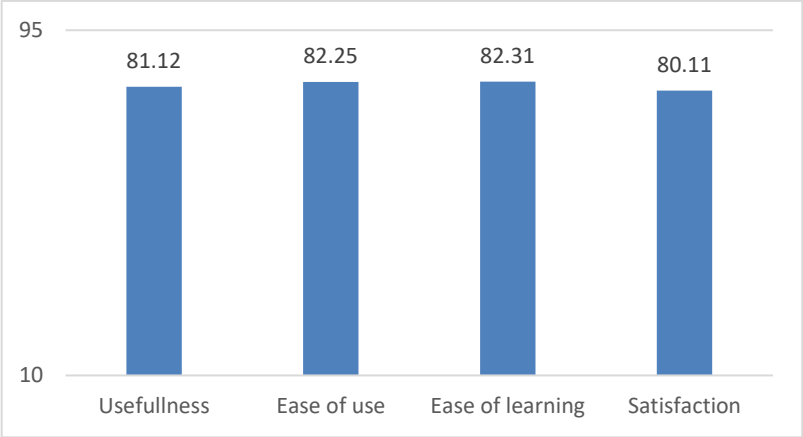

Figure 6. Usability Analysis Graph Using the USE Questionnaire

The results of the usability analysis using the USE Questionnaire are as follows: (1) Usefulness: With a percentage score of 81.12%, it indicates that AR-based DGMATH is highly suitable for students learning spatial geometry; (2) Ease of Use: With a percentage score of 82.25%, it shows that DGMATH AR is easy for students to use in understanding spatial geometry; (3) Ease of Learning: With a percentage score of 82.31%, it is evident that DGMATH AR accelerates students' understanding of spatial geometry; (4) Satisfaction: With a percentage score of 80.11%, it indicates that DGMATH AR provides a high level of satisfaction for students learning mathematics in the digital era.

DISCUSSION

The AR-based DGMATH Book prototype was introduced to students, teachers, and parents. During the event, participants showed great enthusiasm in exploring and experimenting with the DGMATH Book AR learning media. This is particularly relevant as today's students, being digital natives, are naturally drawn to all things digital and are highly familiar with technology.

Figure 7. Outreach Activities for Using DGMATH AR

Teachers need to provide meaningful learning experiences for their students, one of which is by implementing technology-based media such as Augmented Reality (AR). Today's

students belong to the digital native generation, who require technology-based media to boost their learning motivation. Additionally, the use of AR-based learning media like DGMATH, which requires a smartphone for its application, offers students a valuable digital literacy experience by encouraging the positive and productive use of their smartphones. Teachers can indirectly cultivate a habit of using smartphones for educational purposes rather than merely for less beneficial entertainment. However, the implementation of AR-based learning using DGMATH may encounter certain challenges, such as signal strength. This application relies on a strong signal to ensure that explanations, presented as three-dimensional animations, are displayed clearly. Fortunately, such challenges can be easily addressed, as internet connectivity has greatly improved in today's era, with ample Wi-Fi access readily available to support the use of DGMATH AR effectively.

Several studies related to the implementation of AR technology in education, such as those in Gusteti et al. (2023) and Ripaldi & Erpansyah (2024), indicate that the use of AR in mathematics learning can enhance students' learning experiences and significantly improve their motivation and academic achievement (Farika, 2023). The DGMATH AR learning media, for example, offers an engaging learning experience for students by presenting three-dimensional animations with charming and enjoyable digital characters that effectively explain geometric concepts. Additionally, the presentation of books or images of geometric shapes is visually appealing, thereby increasing students' motivation to learn geometric concepts using the DGMATH AR media.

The realistic display of 3D animations significantly enhances students' interest in using the DGMATH Book AR learning media. By using DGMATH AR media in mathematics learning, students will get interesting and meaningful learning so that they can increase students' learning motivation so that student learning outcomes can also improve.

Figure 8. Students' Enthusiasm for Using DGMATH AR

CONCLUSION

DGMATH aims to overcome challenges in learning geometric concepts by providing digital-native students with an immersive AR-based experience that enhances understanding and interest. Accessible via mobile devices, it offers flexible and convenient support for students, teachers, and parents, promoting effective learning at home in the digital era. The feasibility study of DGMATH evaluated technical, financial, and operational aspects, concluding that the AR-based application is highly suitable for Android and iOS devices, providing a sustainable investment value with cost savings on printed materials and improved learning effectiveness. Its user-friendly interface ensures ease of use for teachers and students after minimal training, making it a practical and innovative tool for enhancing mathematics

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learning in the digital era. The conclusion of this feasibility study indicates that DGMATH has the potential to become an innovative and effective learning medium for mathematics, particularly in teaching geometric concepts. The implementation of AR in DGMATH can enrich existing teaching methods and significantly enhance students' understanding of the material.

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