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On Designing Prototype Model of "MathWiz" Mobile Application as an AR-Based Learning Media to Improve Students' Mathematical Proficiency

Luki Luqmanul Hakim, Ahmad Salmun, Yayu Laila Sulastri
Universitas Islam Nusantara, Bandung, Indonesia
Email : luqmanhakim@uninus.ac.id, a.salmun@uninus.ac.id, yayu.ls@uninus.ac.id

KEYWORDS
augmented reality; innovation; learning media; mathematical proficiency; teaching and learning

ABSTRACT
The purpose of this study is to find out designing prototype model of "mathwiz" mobile application as an ar-based learning media to improve students' mathematical proficiency. Learning loss is one type of learning crisis, which refers to the loss of previously learned competencies, incomplete learning at the grade level, and the numerous consequences of not mastering learning at each grade level. As a result, attempts can be made to address these issues through advancing information technology, particularly through augmented Reality (AR)-based learning technologies and artificial intelligence with machine learning. This study aims to create and evaluate the effectiveness of the mobile application "MathWiz" as an AR-based learning media for improving students' mathematical proficiency. The MathWiz program is designed in three stages: listen to customers, build/revise mock-ups, and customer test drives mock-ups. Many respondents from several universities in Bandung participated in this study. According to the results, MathWiz has four advantages: (1) it can display detailed objects and learning materials in real-time; (2) interactivity supported by sophisticated and accurate audio text, video, images, and animation features; (3) has the potential to improve students' mathematical proficiency, and (4) has the potential to increase students' interest in learning mathematics and reduce boredom. The results of this study show that learning mathematics can be made more entertaining and memorable through lecturer innovation.

1. Introduction

The purpose of education is to assist individuals in cultivating an open mindset and innovative approach to effectively navigate and address various challenges and transformations while preserving their unique individuality. Consequently, each instance within the instructional procedure is intentionally structured and arranged to contribute effectively to attaining educational objectives. Education is a transformative process that aims to cultivate and unleash students' full potential. The execution of education in university, which entails lecturers acting as lecturers and students as learners, is achieved through teaching and learning interactions, often known as the learning process.

Currently, the use of advanced technology in education requires the development of innovative learning materials to provide high-quality education and foster further innovation in the field (L L Hakim, Alghadari, & Widodo, 2019). One of the key measures to prevent the lack of student engagement in learning, particularly in learning mathematics, is to prioritize this endeavor. Prior research has consistently shown that mathematics is among the areas where pupils exhibit lower interest levels (Agusti et al., 2018). One of the reasons for the lack of enthusiasm for learning mathematics is the continued use of traditional teaching methods by most math lecturers (Zafirah et al., 2018). Media is an essential tool in learning and cannot be detached from the lecturer. It enhances the learning experience by making it more memorable than traditional teaching methods such as lecturing (lecturer-centered learning) or passive listening (Jazilah, 2016). By incorporating media, students actively engage in the learning process rather than passively receiving information.

Rapid advancements in the digital realm, particularly in computing, compel users to consistently adjust to current developments. Parallel displays of computers indistinguishable from those found in the virtual world are now feasible in the physical world. Further advancements and practical applications of this technology are anticipated to enhance the appeal of the displayed images and enable their utilization as instructional aides that facilitate the learning process. The term for this technology is augmented Reality (Hoff & Azuma, 2000).

Augmented reality-based virtual classes have been developed as an example of the diverse learning applications that can be created with mobile technology and mathematics learning media (Krismanto, 2003). At the very least, this Android-based learning software has successfully altered students' perceptions of math as a tedious and difficult subject that can be made enjoyable through various media and applications (Maskur, Nofrizal, & Syazali, 2017). This indicates that students' perceptions of mathematics have been altered, and learning outcomes have been influenced by implementing technology-driven learning innovations that place students at the center of the learning process.

Augmented Reality is a technological integration that projects a virtual object in real-time into a physical 3D environment while incorporating a 2D or 3D object (Vallino, 1998). Augmented Reality enables users to perceive 3D or 2D virtual objects projected onto the actual world. The objective of augmented reality research, as defined by Haller, Billinghurst, and Thomas (Haller, Billinghurst, & Thomas, 2006), is the development of technologies that dynamically merge computer-generated digital content with the physical environment. Augmented reality in educational media increases student engagement and learning (Meyer, Rose, & Gordon, 2014), (Colpani & Homem, 2015). The entertainment component of augmented Reality increases students' enthusiasm for learning and engaging while bringing it to life. The similarity between Reality and the learning medium, which is to transmit information between the lecturer and the student or between the source and the receiver, clarifies the information delivery between the lecturer and the student during the learning process. This increases learning-related motivation and interest (Keller, 2009). In addition to playing a crucial role in communicating an idea, learning media also acts as an intermediary between students and educational resources (Fry, Ketteridge, & Marshall, 2008) (Kusumah et al., 2020). Students are generally more engaged with the material when the instructor employs instructional materials as learning resources (Falahudin, 2014), (Septianto, Husni Thamrin, & Nugroho, 2014).

The author discusses the importance of instructors' skill and creativity in actively utilizing technology for mathematics learning. Suppose lecturers persist in adhering to traditional concepts and methods of imparting subject matter. In that case, it will lead to subpar attainment of learning outcomes, or in other words, a lack of progress in student skills.

It is important to consider that the implementation of Augmented Reality in education should depend on advancements in Augmented Reality technology and educational philosophy and technology. According to Akayr's statement in (Luki Luqmanul Hakim, Hidayat, Salmun, & Sulastri, 2024), most educational technology developers who use Augmented Reality principles fall into three categories: lecturers creating solutions on an as-needed basis, lecturers with limited knowledge of technology, or developers with limited understanding of education. This aligns with Challenor & Ma's opinion in (Luki Luqmanul Hakim et al., 2024) that educational technology incorporating Augmented Reality is frequently employed solely as a novel means of presenting information without allowing lecturers to actively engage in instructional activities to enhance educational results. Consequently, it is imperative to prioritize advancing educational technology that incorporates Augmented Reality to meet the ongoing educational requirements. An area of educational priority that deserves attention is the achievement of successful learning outcomes. Meanwhile, the students' learning outcomes can be gauged by their mastery of specific abilities in the learning process.

Among the essential abilities to improve is called mathematical proficiency. As a description of a collection of abilities that students must possess and/or master upon completion of their learning mathematics, mathematical proficiency is defined. Mathematical skills consist of five strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Kilpatrick, Swafford, & Findell, 2002).

In connection with the matter of mathematics learning, which the author exposes in this article, several prior studies have observed that, in practice, most lecturers continue to prioritize syllabus fulfillment and textbook selection as learning resources. Consequently, the learning process is structured in a consistent and undemanding way, as the instructor perceives the students as a cohesive unit whose sole requirement is to maintain silence while receiving instructional materials (Ruseffendi, 1988).

The human mind constructs mathematics, associated with concepts, procedures, and logic. Students' creations, investigations, and observations will continue to be incorporated into the process of learning mathematics, which places greater emphasis on this reasoning activity. Therefore, an ideal mathematics learning environment should encompass multiple components, including instructors, learners, the subject matter, and the learning environment (An, Ma, & Capraro, 2011) (Maryam, 2019).

Given the rationale above, researchers developed a prototype of the Mobile Application "MathWiz" as an Augmented Reality (AR) based educational tool to enhance students' mathematical abilities. MathWiz is an Android application designed as an augmented reality learning tool. This design is intended to facilitate students' active learning, enhancing their mathematical proficiency. The MathWiz mobile application can be loaded on Android-based smartphones owned by students. Therefore, students can acquire the course content during class and reinforce their learning outside the classroom using their smartphones. This is possible due to the current affordability and accessibility of smartphones.

The purpose of this study is to find out designing prototype model of "mathwiz" mobile application as an ar-based learning media to improve students' mathematical proficiency.

2. Materials and Methods

Explaining The authors employed the prototype model approach to develop the application in this study. They drew inspiration from several prototype model research specialists frequently cited by earlier researchers (Pressman, 2016)(Bernhammer, Van Kuik, & De Breuker, 2014). The prototype model consists of three essential stages: (1) listen to customers, (2) build/revise mock-ups, and (3) customer test drives mock-ups.

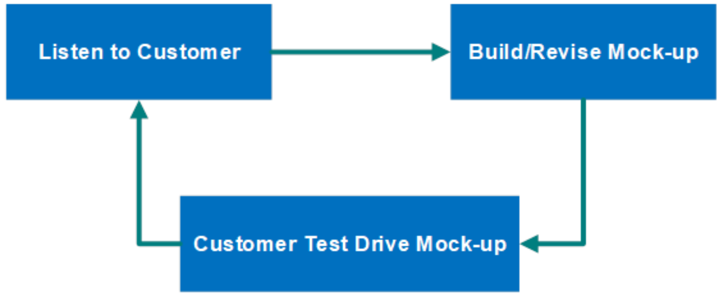

Figure 1. Stages of the Prototype Model Research Method

The prototyping process commences with analyzing consumer requirements, followed by the author's development of the desired digital instructional aids requested by the customer. Students are the intended consumers, whereas lecturers are the customers in this scenario. During the subsequent phase, the instructor formulates the objectives and requirements of the students and gathers relevant data. The utilized data sources include primary and secondary data sources. Primary data sources were acquired through direct observation to assess the traditional teaching aids frequently utilized in school geometry textbooks. The data acquired in the form of documented outcomes is essential for creating the design and three-dimensional (3D) objects as markers. In addition, secondary data sources are acquired through the compilation of literature studies, which serve as fundamental information for constructing markers.

The design phase is completed quickly during the build/revise mock-up stage, and the design represents all known characteristics of the software and serves as the foundation for prototyping. The next step is to design or create digital teaching aids based on the lecturer's needs for learning objectives. The design process begins with modeling architectural objects in 3D modeling software. Furthermore, the researcher designed and built augmented reality applications by utilizing the Meta Spark platform technology, namely Meta Spark Studio v.171.1.0.64.258, as a third party in displaying Augmented Reality features. In addition, PHP 8.1.10 is also used with the Framework using Laravel 9.52.15, and Bootstrap v5.1.3 with MySQL as a database.

The final stage is user testing (evaluation) of the mock-up. This stage is used to analyze the prototype that was created and to clarify software needs. The evaluation tries to determine whether the digital props comply with the customer's initial needs. After the digital props have been tested, the different flaws that exist in the digital props will be revealed, as well as whether the props agree with the user's initial needs. If it is inappropriate, the design will be restarted from the beginning.

3. Result and Discussion

MathWiz is an AR-based learning media, as explained in the background of this article. This augmented reality-based learning media of mathematics is expected to offer a fun learning environment for pupils, making learning less rigid and tedious. The MathWiz application has the following features: Material, Exercise, Examination, Exploration, and Forum.

The material feature presents learning mathematics materials and books that already have markers in the MathWiz app. The material presented in the MathWiz program includes extra capabilities such as AR, Video, and Audio text. The exercise feature includes exercise questions and explanations of solutions. Practice questions are designed to assess students' grasp of the content covered. This feature is included in all materials so lecturers can track students' progress in achieving maths abilities more explicitly in each subject. The examination feature allows students to use essay questions as exam questions. This feature is used to assess students' overall comprehension of the topic. The exploration feature contains articles related to the content being studied. This feature is designed to provide students with supplementary information so that they not only grasp the topic but also comprehend the history, behind-the-scenes, or mathematician figures behind the material they are studying. Finally, there's the forum feature. The MathWiz application's forum function allows users to exchange ideas online via chat. This forum feature allows users to have real-time discussions among students and between students and lecturers. With the forum function, students are required to discuss their mathematical ideas with one another, forming a communicative learning environment. Figure 2 below shows how the steps of using MathWiz work.

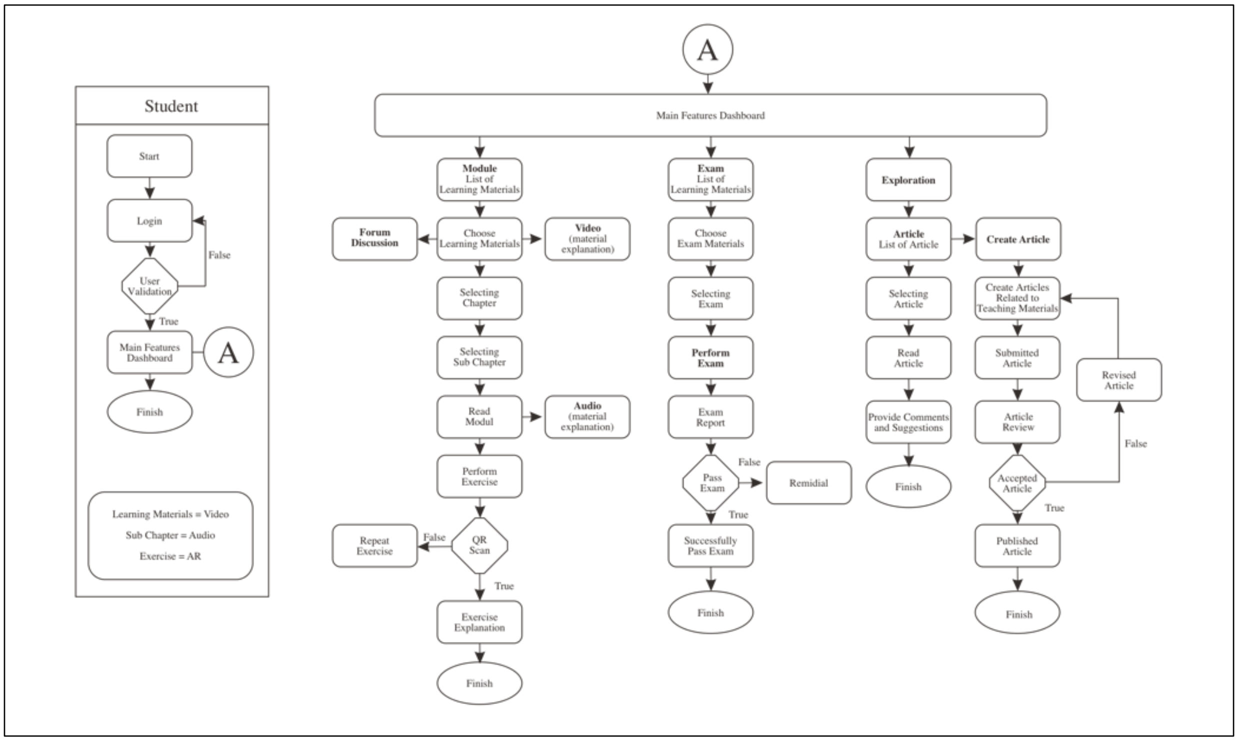

Figure 2. ***Flowchart of the MathWiz app***

The process will start by opening MathWiz on the smartphone. Then, the user selects the material menu to start learning. To bring up AR assistance, users can click on the menu burger and select AR, then point the smartphone camera to the marker on the teaching material. Furthermore, 3D objects will appear according to the marker. The working mechanism of MathWiz is presented in the figure.

Listen to Customers

Students are currently accustomed to learning through printed and electronic books. Based on the type of device utilized, it may be stated that electronic books are predominantly read on smartphones. As a result, the AR-based learning media framework for improving students' mathematical proficiency begins with learning resources that students may access, namely learning materials in math books and other media accessible via smartphones. After that, the two learning aids are integrated to form a smart book.

Smartbooks are printed books with markers in certain areas, and smartphones may be used to scan markers on smartbooks using the AR concept. Scanning the marking yields 3D objects, 2D/3D animations, audio text, and/or video. This method results in the creation of AR-based learning material. The following are the contents of this AR-based learning media: Learning Path, Content, Report, Math Proficiency (MP)-Based Evaluation, MP-Based Testing, Exploration, and Self Evaluation. Thus, AR-based learning media can identify students' mathematical proficiency curves.

An AR-based learning media framework has been successfully developed to improve students' mathematical proficiency. The Framework is illustrated in Figure 3.

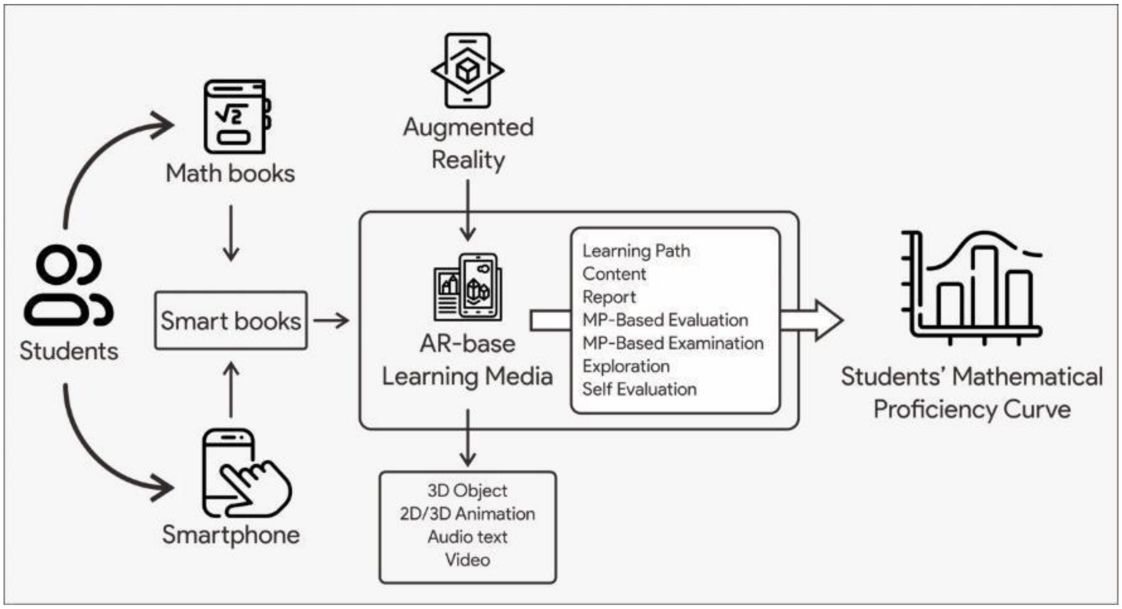

Figure 3. Framework Design of AR-Based Learning Media to Improve Students' Mathematical Proficiency [17]

Build/Revise Mock-ups

The following stage involves developing or creating MathWiz, a digital learning media based on user demands to accomplish learning objectives. Splash Screen Page, Onboarding Page, Login Page, Homepage, Course Page, Learning Material Page, Material Page, Material Content Page, Exercise Page, Examination Page, Remedial Page, and additional application support pages like History, Articles, and Profile are just a few of the pages that make up MathWiz.

The MathWiz logo appears on the splash screen page as a way to travel from there to the Onboarding page. When a user interacts with the program for the first time, they will only see the Onboarding page, which is an introductory page containing an application description. Users will be sent from the Onboarding page to the login page and ultimately to the Homepage, the main page. Users will see menu options on the Homepage, including the Course, Exercise, Examination, and Remedial menus as shown in Fugure 4. Students can explore information and topics related to the material being studied using the article menu on the material content page, which also has augmented reality technology.

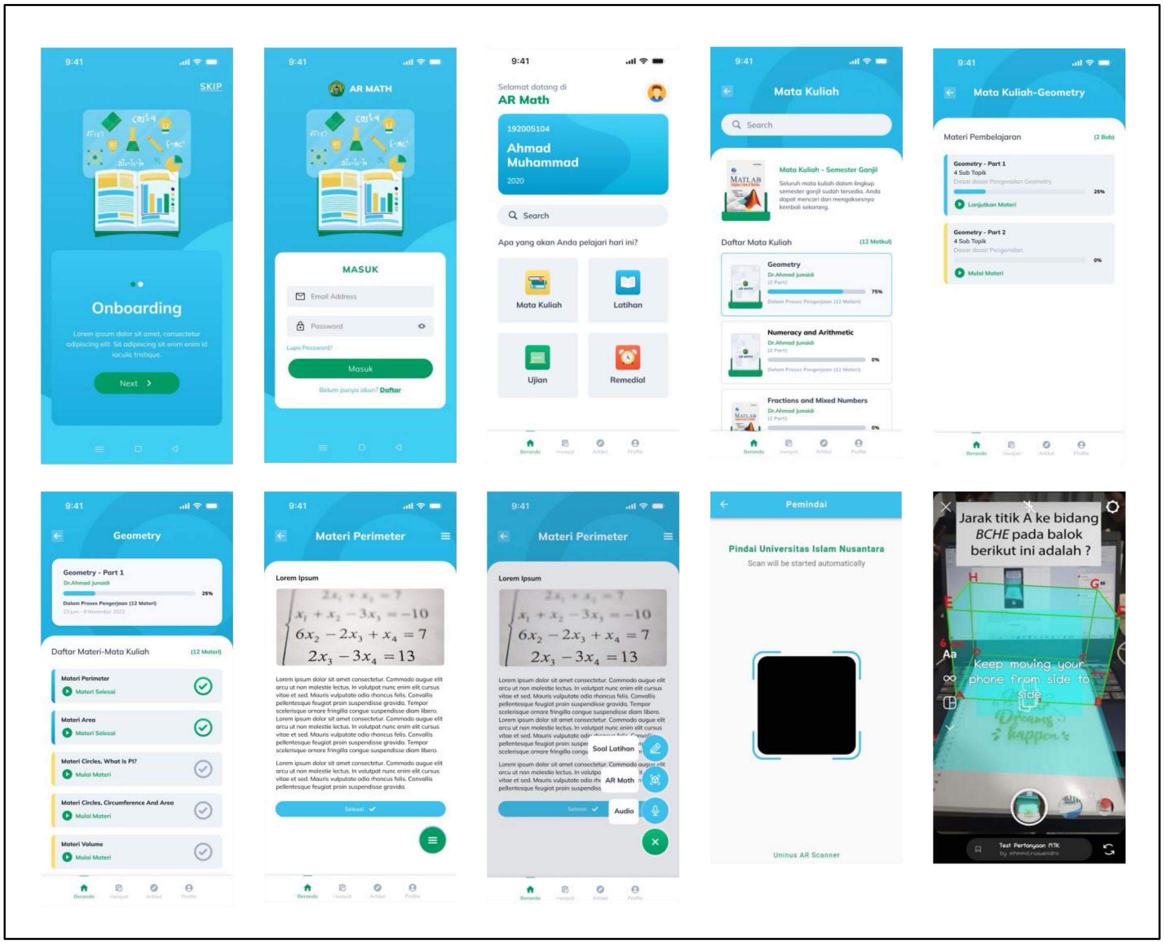

Figure 4. MathWiz Screen Capture

Customer Test Drives Mock-up

The final step in this research is testing, specifically digital learning media and markers. Black-box testing approaches are used to evaluate digital learning media like mathematics learning material. These test drives will assess the effectiveness and success of the features contained in these digital learning media. The findings of assessing the effectiveness and success of applications developed during the research will be given in Table 1.

Table 1. MathWiz Mobile Application Effectiveness Testing Results

Testing	Scenario	Expected results	Testing Results	Conclusion
Splash Screen Page	Opening the app	Works well and can be opened	As Expected	Valid
Onboarding Page	Selecting SKIP (to go to the log-in page) or the NEXT button to view the app description	Move to the next page according to the action performed	As Expected	Valid
Login Page	Fill in the data and press the ENTER button	The form can be filled in, and the login button works so the page moves to Hompage.	As Expected	Valid
Homepage	Choose a menu 1. Material Search 2. Course Content	Move to the next page according to the selected menu	As Expected	Valid

Testing	Scenario	Expected results	Testing Results	Conclusion
	3. Exercise 4. Examination 5. Remedial 6. History 7. Exploration: Related Articles 8. Profile			
Course Page	Choose a menu 1. Course Search 2. Course List	Move to the next page according to the selected menu	As Expected	Valid
Learning Material Page	Select the material menu to be learned	Move to the next page according to the selected menu	As Expected	Valid
Material Page	Choosing a topic	Move to the material content page according to the selected topic	As Expected	Valid
Burger Menu on the content page	Select button 1. Practice Questions 2. AR Math 3. Audio	Log in to the selected service based on the button	As Expected	Valid
Practice Problem Button	Selecting exercises based on the topic learned	Enter the exercise page according to the topic learned	As Expected	Valid
AR Math Button	Object compatibility with markers	Display 3D objects through markers	Less compatible	Less Valid
Audio Button	Text-to-voice conversion	Issuing text-based explanatory sounds on the topic studied	Not as Expected	Invalid
Examination Page	Choose examinations based on the chapter that has been completed	Move to the Examination contents page according to the selected examination	As Expected	Valid
Remedial Page	Choose Remedial based on incomplete examination results	Move to the contents page Remedial according to the selected remedial	As Expected	Valid

Based on the results of tests conducted on several respondents from several universities in Bandung, the analysis shows that digital learning media are by expectations with a high level of validity and by the desired expectations and objectives. In other words, the design of digital learning media applications can be used as a learning media appropriately and successfully. To bolster their findings, the authors examined the camera detection mechanism of each marker at a specific distance. Figure 5 depicts the findings of a test analysis conducted by a team of professionals enlisted by the author as analysts and assessors.

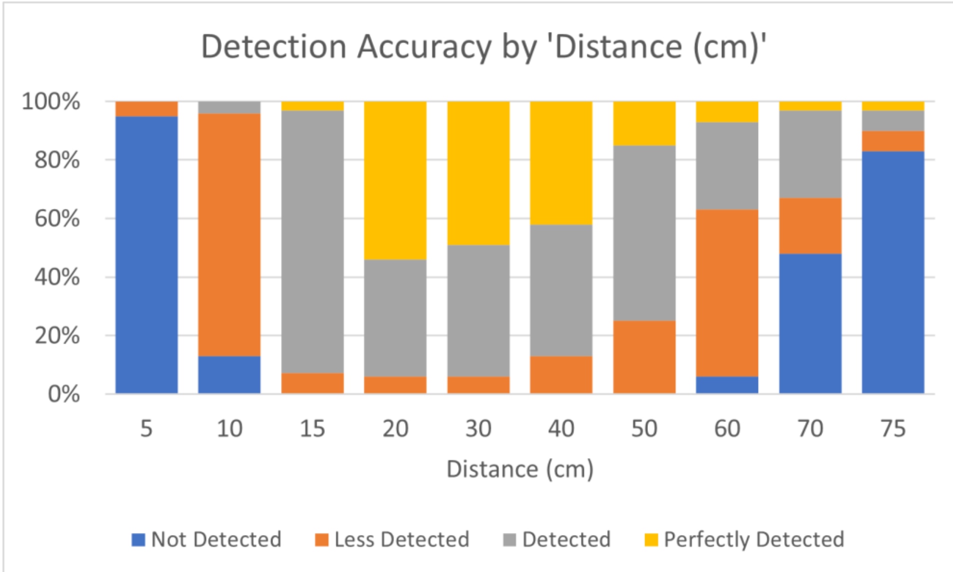

Figure 5 Chart of the Test Results of the Camera Detection Process for Markers

In Figure 5, it is evident that the marker is undetectable at a 5 cm distance, and its detectability diminishes in certain devices with specific specifications. However, many devices exhibit marker recognition at a distance of 10 cm under conditions of sufficient lighting and optimal camera focus. The optimal detection range for markers lies between 15 and 50 cm. As the device moves farther away from the marker, the detection capability gradually diminishes.

To augment the interest level, an examination of the findings will be accompanied by an analysis of diverse theories and research outcomes from prior scholars who have grappled with the identical context and matter. The author previously stated that mathematics is among the subjects students find tedious to learn. Indeed, lecturers are aware of this issue; however, a significant proportion of them lack the requisite pedagogical and professional expertise to surmount the challenge posed by students' learning difficulties (Murniyetti, Engkizar, & Anwar, 2016) (Yusnita et al., 2018). In contrast, the advancement of digital technology in the twenty-first century allows lecturers to impart subject matter creatively for mathematics learning (Suharso, 2012). In mathematics, students can acquire knowledge through three fundamental facets: enactive, iconic, and symbolic. The enactive stage consists of learning through the manipulation of tangible objects or objects, the iconic stage consists of learning through the manipulation of images, and the symbolic stage consists of learning mathematics through manipulating symbols (Rusnandi, Sujadi, & Fauzyah, 2016). Learning mathematics entails constructing or developing concepts and principles; learning must be active and dynamic, not merely inert and static instruction (Ningtias, Hartoyo, & Suratman, 2013). Learning mathematics requires an adequate learning strategy design, one of which is the existence of tools to bridge the abstraction of mathematical concepts. Prior research has demonstrated that the implementation of digital technology in the form of Android applications, which the authors of this study do, has a significant impact on student learning outcomes (Wardani & Sari, 2016) (Billinghurst & Duenser, 2012) (Cai, Chiang, Sun, Lin, & Lee, 2017). In addition, using augmented reality technology in learning can also improve students' visualization skills and promote student-centered learning (Ali, Johari, & Ahmad, 2023). Thus, augmented reality technology can be more effective than conventional teaching methods in improving students' visualization skills.

Augmented Reality is a geometry learning medium visually presenting instructional content in three dimensions. Based on the findings and effectiveness evaluation of the application conducted by the authors in this research, it has been demonstrated that augmented reality-based virtual geometry applications can generate a novel, more engaging environment for students to learn mathematics. Furthermore, the application can alter students' perceptions of mathematics, which were previously regarded as more challenging and inflexible, to the extent that the learning environment rapidly becomes monotonous and saturated. Previous scholars have reached the same conclusion as the present one, which is that traditional methods, media, and approaches to learning mathematics no longer apply to the advancement of education in the twenty-first century (Dunleavy & Dede, 2014). On the contrary, lecturers are expected to exhibit ingenuity and continuously enhance their pedagogical and professional proficiencies to effectively confront the demands of an ever more intricate and arduous educational landscape. Ultimately, the author posits that learning is a holistic and dynamic process and that the effectiveness of a learning endeavor is not contingent upon a well-designed curriculum, well-equipped learning facilities, or substantial welfare. Different complex factors, including the proficiency and ingenuity of the instructor, exert an influence on the effectiveness of the learning process. The student also possesses qualities such as talent, interest, and willingness. However, to cultivate these qualities, lecturers must employ diverse strategies. For instance, the author of this study utilized Android applications designed as augmented Reality to facilitate mathematics learning. The research results by (Rejekiningsih, Maulana, Budiarto, & Qodr, 2023) show that Android-based augmented reality technology can improve student interest and learning outcomes in science subjects. This study shows that students have a high need for innovative and interesting learning media, and using augmented reality technology can help students better understand science concepts. Because the ambiance of student learning within the classroom is predominantly influenced by how the instructor structures the learning process. Effective learning design by the instructor significantly affects learning outcomes; conversely, inflexible and uninspiring learning design will also affect the learning outcomes.

4. Conclusion

In conclusion, the AR-based learning media framework, MathWiz digital learning platform, and digital learning media collectively represent a transformative approach to education. The AR framework seamlessly integrates traditional materials into smartbooks, providing an interactive learning experience through augmented reality technology. MathWiz, developed with meticulous mock-up design, offers a structured user journey and incorporates augmented reality on the Material Content page for enhanced exploration. Additionally, tests on digital learning media demonstrate their efficacy, particularly within a specific camera detection range. The integration of augmented reality in geometry learning not only makes mathematics more engaging but also signifies a potential shift in educational paradigms. The dynamic nature of the learning process emphasizes the role of instructors in adapting pedagogical methods and utilizing innovative tools to meet evolving student needs, ultimately fostering improved interest and learning outcomes in science subjects. Together, these initiatives showcase the potential to reshape education and enhance students' proficiency in various subjects.

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