Enhancing Learning Experiences Using Markerless Augmented Reality in Computer Hardware Education

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ABTRACT

Augmented Reality (AR) technology is one way to improve students' learning experience. Using Markerless AR, the computer hardware introduction process for junior high school students will be more effective through the development and deployment of an application known as ARWONDERS. The goal of this study was to determine the applicability and impact of Markerless AR technology in the field of education. The researcher aimed to assess whether ARWONDERS significantly improves students' learning experience in terms of understanding the concepts of computer hardware. In general, the research and development model using the waterfall model includes requirements, systems, and software design, implementation, testing, and maintenance. Additionally, some of the software tools to be used involve a blender for 3D, while the entire AR is implemented in Unity. The application was validated through expert judgment and user testing. The experts were media experts, material experts, and junior high school students. The results show that the ARWONDERS application is very feasible and effective, and can improve junior high school students' understanding of computer hardware. The expert and user ratings were very high, indicating that ARWONDERS is superior to other applications. Comparing this paper to previous research, Markerless AR represents major technological innovations because it allows more flexibility. In conclusion, this research reflects the potential of Markerless AR technology to offer students more realistic and flexible learning activities to develop digital age skills.

Keywords: *Augmented Reality, Computer Hardware, Educational Technology, Markerless Technology.*

1. INTRODUCTION

In this ever-evolving era, education is undergoing a significant transformation owing to technological advances, particularly through the application of augmented reality (AR), which integrates the real and virtual worlds in three dimensions [1]. The use of AR in the context of learning has proven helpful in explaining complex materials that are more easily understood by students. Although not widespread, the potential of AR to increase student motivation and engagement in the learning process is enormous. By utilizing AR's uniqueness in presenting information visually and interactively, this approach can present a more interesting and motivating learning experience for students, helping them to be more active in exploring knowledge and understanding [2].

The application of augmented reality (AR) in a learning context has become a significant research focus in an effort to make complex subject matter easier for students to understand. In many schools, technology has been adopted as an aid in the learning process, with the use of AR as a promising approach. For example, research conducted by [3] successfully developed AR applications that include text, images, and three-dimensional objects as a means to understand and learn computer hardware components. By utilizing the advantages of AR in presenting information visually and interactively, this application opens new opportunities for presenting materials that are more interesting and relevant to students. Through this approach, it is expected that students' understanding of complex materials, such as computer hardware components, can be significantly improved, bringing a positive impact on the learning process in the educational environment and AR technology learning approaches can bridge the gap between theoretical and practical knowledge and make learning more interactive and student-centered. By integrating AR, teachers can create and provide immersive experiences where students can interact with virtual objects, in this case computer hardware

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components, in real time so that previously complex learning can be carried out easily.

At the secondary education level, especially in junior high school (SMP), understanding computer hardware has great significance because it is the foundation for understanding advanced concepts in computer science. Introductory hardware materials generally include an understanding of basic components such as the mouse, RAM, and hard disk. Mastery of these concepts equips students with the necessary knowledge to understand how computers work and to prepare them to study further aspects of computer science. Therefore, teaching computer hardware at the secondary education level plays a crucial role in preparing the younger generation to understand and develop information technology in the future.

Some research has implemented technology on the use of augmented reality learning media in computer hardware introduction materials, such as those conducted by [4], [5], and [6]. Other studies from [7] and [8] have implemented AR technology for learning the introduction of computer hardware.

Some researchers, such as [9] and [10], have conducted research using augmented reality (AR) technology for learning computer hardware recognition. However, one of the obstacles that arise from this research is the need for markers to display three-dimensional objects. The use of markers in AR applications is impractical because it requires students to always carry the markers to see three-dimensional objects. This obstacle demonstrates the need for further research to develop a more practical and effective method for recognizing three-dimensional objects in AR in the context of computer hardware learning. Thus, this study aims to overcome these challenges and provide a more efficient solution for using AR as a learning tool in the classroom.

In the context of learning development, especially in the introduction of computer hardware, an interesting solution has emerged in the form of markerless augmented reality. This technique, introduced by Endra & Dian (2019), eliminates the need for markers for augmented reality (AR). Thus, students are no longer tied to additional devices such as markers to visualize three-dimensional objects. The use of markerless AR offers a more engaging and realistic learning experience for students, which can improve their understanding of computer hardware materials. With this technology, it is hoped that learning will become more interactive and have a positive impact on students' understanding and interest in computer science.

The results of observations at partner schools in the Sukoharjo area illustrate that the conventional teaching approach is still dominant in introducing computer hardware materials. In this approach, the teacher directly explained the material from the textbook to students. The impact of this teaching method is the difficulty for students in understanding the material, especially in informatics subjects, because they tend to lose focus when the teacher explains. In addition, the students' computer operational skills were low. It should be noted that in the partner school, there was no teacher with an informatics education background teaching the subject. Instead, religious teachers fulfill the teaching role of informatics subjects.

The main objective of this research is to investigate the effectiveness of markerless augmented reality (AR) implementation in learning hardware introduction materials for junior high school students of partner schools in the Sukoharjo area. By utilizing this innovative AR technology, it is expected that students can easily understand and remember the components of computer hardware. Through the application of AR in the learning process, it is expected that there will be an increase in student learning achievement in informatics subjects. By providing a more interactive and visual learning experience, AR can help students become actively involved in the learning process and improve their understanding of the material being taught.

2. METHOD

This study adopts a research and development (R&D) approach using the waterfall model. The Waterfall model is an approach that consists of several main stages, namely, requirement definition, system and software design, implementation and unit testing, integration and system testing, and operation and maintenance, as described by [11] in Figure 1. In the context of this research, the waterfall model aims to provide a structured and organized framework for the development of Augmented Reality (AR) technology-based solutions for learning computer hardware introduction material for students.

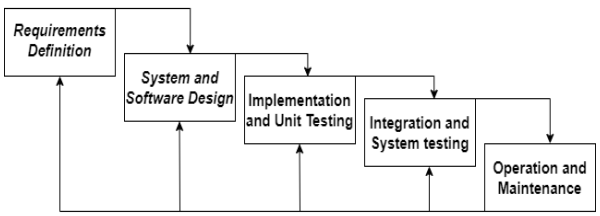

Figure 1 Waterfall Model

In developing the ARWonders application, several software packages, such as Blender for 3D modeling, Unity for software development, and Vuforia as an augmented reality library, are used. After completion of the development, the application will be validated by three experts : a lecturer in the Informatics Engineering Education Study Program at Universitas Muhammadiyah Surakarta as a media expert, an informatics teacher at one of the partner junior high schools as a material expert, and testing by users using the System Usability Scale (SUS) questionnaire with a total of 15 respondents. Testing to

evaluate the improvement of material understanding will use pre-test and post-test tests on 10 partner junior high school students. This structured methodology is expected to provide valid and significant research results in measuring the effectiveness of the use of augmented reality technology in improving the understanding of computer hardware introduction material in the educational environment.

3. RESULT AND DISCUSSION

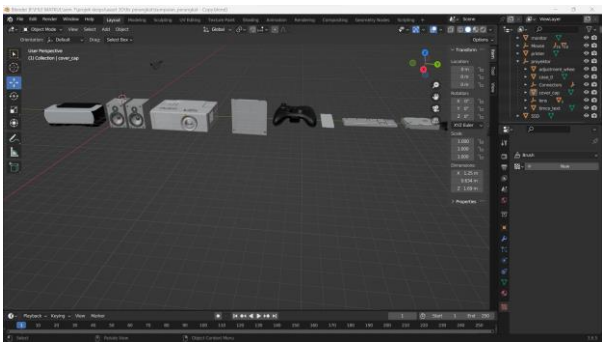

Figure 2 Modelling 3D Model

The application development starts with creating 3D modeling using Blender software, followed by the implementation of markerless augmented reality technology using Unity software. Figure 2 shows the process of creating 3D models of computer hardware equipment, which is performed through the modeling process using Blender software. This stage is a key step in the development of an application that aims to provide a more interactive and engaging learning experience for users through augmented reality technology.

Figure 3 Main Menu

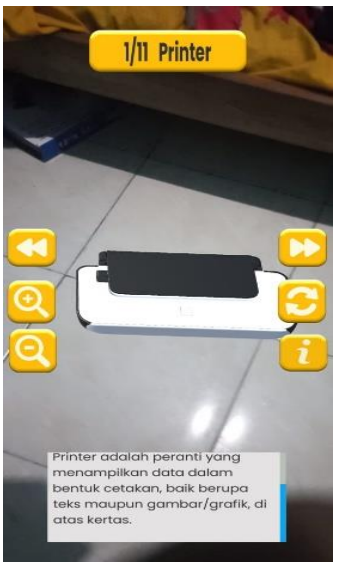

Figure 4 Augmented Reality Menu

Figure 3 shows a home view of the ARWONDERS application. In this view, there are several buttons that have their respective functions, including: first, the "Tujuan" button which contains the purpose of developing this application by its developer. Second, the "AR" button directs users to the Augmented Reality (AR) menu, where they can experience an interactive experience by adding virtual elements into the real environment. Third, the "Kuis" button allows users to answer the quiz questions presented. Next, the person icon contains information about the developer or media developer involved in creating the application. Finally, the ask icon which provides an explanation of the use of the application for users.

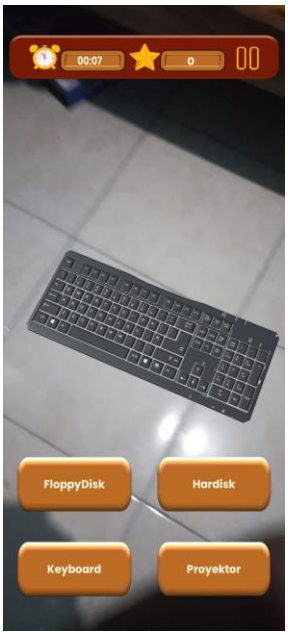

Figure 5 Quiz Menu

Figure 4 shows the Augmented Reality (AR) page, where the augmented reality (AR) menu provides an interactive experience by adding virtual elements to the real environment. Users can perform various interactions, such as rotation, changing 3D objects, zooming in and out, and knowing the description of the 3D objects that appear. These features give users the ability to interact directly with virtual objects displayed using augmented reality technology.

Figure 5 depicts the quiz page in the application, where users can participate in the quiz. In this quiz, users were given 10 seconds to answer each question by selecting the correct answer. After 10 s, the question changed automatically. There are a total of 10 questions in this game, where the user will receive 10 points when successfully answering one question correctly, but the points will be reduced by 10 if the answer given is wrong. Through this quiz feature, it is hoped that users can test and improve their understanding of computer hardware introduction materials in an interactive and fun way.

After the application development process was completed, the next step was to conduct validation by media experts. In this study, validation was conducted by three lecturers from the Informatics Engineering Education Study Program at Muhammadiyah University Surakarta. The Likert method was used in the validation test. The results of the assessment conducted by media experts are shown and interpreted further in Table 1.

$$\text{Feasibility Percentage (\%)} = \frac{zskor\ obtained}{zskor\ max} \text{ x } 100\% \quad (1)$$

$$\text{Feasibility Percentage (\%)} = \frac{217}{264} \text{ x } 100\% = 82\%$$

Table 1 Likert Scale

Feasibility Percentage	Interpretation
81%-100%	Very Feasible
61%-80%	Worth
41%-60%	Simply
21%-40%	Less Feasible
1%-20%	Not Feasible

After calculating the percentage according to a predetermined formula, the final result was 82%. This result was then compared to the percentage scale listed in Table 1. The interpretation of the calculation results shows that the media that has been developed have a very high level of feasibility for application.

In the next stage of this study, a material expert validation test was conducted. Researchers carried out testing on one validator, a junior high school teacher in Surakarta. The results of the validation test were processed using a Likert test calculation. This process aims to ensure that the application developed not only meets technical standards but is also relevant and in accordance with the needs and standards of the material taught in the context of computer learning at the junior high school level.

$$\text{Feasibility Percentage (\%)} = \frac{zskor\ obtained}{zskor\ max} \text{ x } 100\%$$

$$\text{Feasibility Percentage (\%)} = \frac{45}{48} \text{ x } 100\% = 93\%$$

After performing the calculations based on a predetermined formula, the final result was 93%. The interpretation of the percentage table presented confirms that the media that has been developed have a very high level of feasibility for application. Based on this result, it can be concluded that the application or media designed and developed in this research meets the standards required for effectiveness and usability in a learning context.

In the user test phase, 15 students tested the application using the SUS (System Usability Scale) questionnaire. In this test, students were asked to assess the usability of the system based on the criteria set out in the SUS questionnaire. The results of this user test are key in evaluating the user experience of the developed application.

$$\bar{x} = \frac{\sum x}{n} \quad (3)$$

$$\text{Average Score} = = \frac{1242}{15} = 82{,}8$$

The next step was to correlate the results with the System Usability Scale (SUS) score documented in

Figure 6. The analysis results in Table 3 showed that the average value of the user test reaches 82.8. Based on the scale category listed in Figure 6, the value is included in the grade "B" category, which indicates "EXCELLENT." Thus, it can be concluded that the ARWONDERS app meets the necessary standards for acceptance by users.

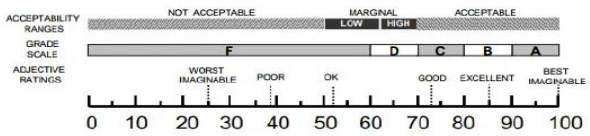

Figure 6 SUS Score

To see the impact on learning outcomes, pretests and posttests were conducted with 10 students as respondents. The results of the pre-test and post-test were measured using the N-Gain Score calculation. The N-Gain Score is a method used to evaluate the improvement of students' understanding after following a learning intervention, such as the ARWONDERS application. By comparing pre-test and post-test scores, information will be obtained on the effectiveness of the application in improving students' understanding of computer hardware introduction material.

$$\text{N Gain} = \frac{Posttest\ Score - Pretest\ Score}{Max\ Score - Pretest\ Score} \quad (4)$$

Table 2 N-Gain Score

Result N-Gain Score	
No	N-Gain Score(%)
1	57.14
2	60.00
3	60.00
4	90.00
5	57.14
6	20.00
7	62.50
8	33.33
9	73.33
10	66.67
Average	58,0119
Minimum	20.00
Maximum	90.00

Based on the results of the N-Gain Score test calculation documented in Table 2, the average value of the N-Gain Score obtained is 58.0119 or equivalent to 58%, which is included in the "quite effective" category. Thus, it can be concluded that the use of the ARWONDERS application has proven to be effective in improving student learning outcomes when computer hardware is introduced in informatics subjects at partner schools. The results of this evaluation show that the application has a significant positive impact on students' understanding and learning achievement, in accordance with the objectives of application development.

Based on the results of research involving validation by media experts, material experts, and users, several significant findings were obtained. First, the results of media expert validation showed that the ARWONDERS application was rated "Very Feasible" with a score of 82% in Likert calculation, and an average value of 0.79 in Aiken's V calculation which falls into the "High" category. Meanwhile, the material expert validation showed a higher assessment, with a score of 93% in Likert calculation and an average value of 0.91 in Aiken's V calculation, also in the "Very Feasible" category. Direct testing of 15 users resulted in an average score of 83, which falls into the "EXCELLENT" category in the SUS scale grade. Furthermore, the results of pretest and posttest testing by 10 students showed an increase in understanding of 58% in the "moderately effective" category based on the N-Gain Score. Thus, it can be concluded that the ARWONDERS application is feasible to use and has the potential to improve students' understanding of computer hardware material. This finding makes a significant contribution to the context of computer learning in school environments.

This research can be compared with previous research conducted by [12] and [13] in developing learning applications for introducing computer hardware using Augmented Reality (AR) technology. Similar to this research, the two previous studies involved the validation stages of media experts, material experts, and user testing to evaluate the effectiveness of the developed applications. In addition, this research also refers to research conducted by [14] and [15], which applied AR technology in learning the introduction of computer hardware. Comparing the results and methodology of this research with previous research can provide greater insight into the development and potential of AR technology applications in improving learning in the field of computer hardware recognition.

Table 3 SUS Score

Score										**Sub Total**	**Total**
Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**		**(Sub Total x 2.5)**
4	4	3	4	4	3	4	4	3	3	36	90
4	3	4	4	4	4	4	3	3	4	37	93
4	2	3	3	4	3	3	4	3	3	32	80

Score										Sub Total	Total
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		(Sub Total x 2.5)
3	4	4	4	3	4	4	3	3	3	35	88
4	3	4	2	4	4	3	1	4	3	32	80
3	2	3	3	3	3	3	3	1	3	27	68
3	3	3	4	4	3	4	3	2	2	31	78
4	4	4	4	4	4	3	4	3	3	37	92
4	3	3	4	3	3	3	4	4	4	35	88
3	3	4	3	4	4	4	4	3	3	35	88
4	3	3	2	4	4	4	3	3	3	33	83
3	4	2	4	4	4	1	3	4	3	32	80
3	4	4	3	4	3	4	3	4	1	33	83
4	3	3	4	3	3	4	3	3	3	33	83
3	2	2	3	3	3	3	2	3	1	25	63
	Average										82,8

In an innovative context, this research distinguishes itself by adopting markerless augmented reality technology, which overcomes the limitations of previous research using markers. The markerless AR technique, as described by [16], provides flexibility without dependence on markers, thus making hardware recognition learning more interesting and realistic for students, with the potential to improve their understanding. This research aims to develop a computer hardware ARWONDERS application to help students improve their understanding of computer hardware introduction materials. The validity and feasibility of the application were tested through trials involving three media experts, one materials expert, and user testing. By integrating AR Markerless technology, this research makes a significant contribution to improving the effectiveness of learning in the field of computer hardware introduction, especially in the secondary education environment.

4. RESULT AND DISCUSSION

Based on a comprehensive exploration of Augmented Reality (AR) technology in the context of learning computer hardware introduction material for junior high school students, this research culminates in several significant conclusions. First, the development and implementation of the ARWONDERS application utilizing markerless augmented reality represents a promising advancement in educational technology. By eliminating the need for markers, this innovative approach enhances the learning experience, offering students a more engaging and immersive way to interact with computer hardware concepts. Second, the thorough validation process involving media experts, material experts, and user testing demonstrated the high feasibility and effectiveness of the ARWONDERS application in improving students' understanding of computer hardware. The positive evaluations of experts and users alike underscore the potential of AR technology to enhance learning outcomes in the school environment. Third, a comparison with previous research highlights the unique contribution of this study in adopting markerless AR technology, which addresses the limitations of marker-based approaches and offers greater flexibility and realism in learning. Overall, this research underscores the importance of leveraging technological innovations such as markerless AR to enrich the educational experience and empower students with the knowledge and skills needed for the digital age.

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