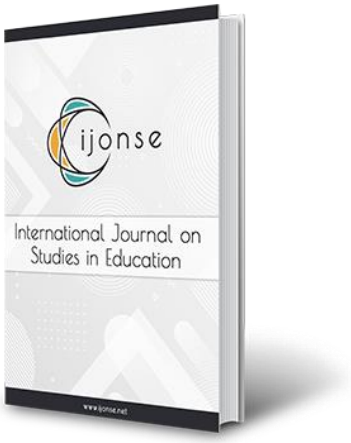

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Augmented Reality-Based Learning Media in Computer Systems Subjects

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Augmented Reality-Based Learning Media in Computer Systems Subjects

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Abstract

This research aims to develop Augmented Reality (AR)-based learning media in the Computer Systems subject at SMK Negeri 2 Argamakmur, with the hope of increasing the effectiveness and involvement of students in the learning process. This study uses the Research method and Development (R&D) with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model. The subjects of the study consisted of 30 grade XI students at SMK Negeri 2 Argamakmur. Data collection instruments included questionnaires to measure student and teacher responses, and tests to assess the increase in conceptual understanding. The media feasibility test was carried out through validation by material experts and media experts, as well as limited trials. The results showed that AR-based learning media received a "very feasible" rating from material experts with a score of 88.5% and from media experts with a score of 91.2%. Testing the effectiveness of the media on student understanding showed an increase in learning outcomes with an average pre-test score of 65.3 increasing to 82.7 in the post-test, with a rise of 26.5%. Student responses to this learning media were also very positive, with a percentage of satisfaction reaching 89.4%. Based on these results, it can be concluded that the AR-based learning media developed effectively improves student understanding and can be used as a learning medium in the computer systems subjects.

Introduction

Vocational education, especially in Vocational High Schools (SMK), has a strategic role in preparing the young generation to be ready to work and have technical skills relevant to industry needs. One of the biggest challenges in vocational education is how to make the learning process more interactive, contextual, and relevant to the needs of the dynamic world of work. SMK not only teaches theory but also practical skills that require a deep understanding of various technical concepts, including in the field of Computer Systems.

The Computer Systems subject in vocational schools, such as in SMK Negeri 2 Argamakmur, covers complex and abstract materials, such as computer architecture, hardware components, and network systems. Understanding these materials requires a learning approach that can bridge theory and practice effectively. Unfortunately, conventional learning methods, such as textbooks and static visual presentations, are often inadequate to explain these concepts clearly and in-depth.

For example, in studying computer architecture, students are required to understand how various components such as CPU, RAM, motherboard, and other hardware interact with each other. However, with traditional learning methods, students often only see two-dimensional illustrations of these components, which do not provide a complete picture of how the components work. Likewise, in the material on computer networks, limited visualization and simulation often make it difficult for students to understand concepts such as network topology, communication protocols, and data transmission processes.

Therefore, innovation is needed in learning methods that can present a more immersive, interactive, and contextual learning experience (Cakir et al., 2019; Ozturk, 2023). One solution that is now starting to be widely developed is the use of Augmented Reality technology. Reality (AR). AR is a technology that allows users to view the real world with the addition of digital elements generated by a computer, usually through a device such as a smartphone, tablet, or special glasses (Abdusselam & Kilis, 2021; Alper et al., 2021; Al-shummarani & Nasr, 2022; Hasibuan & Chairad, 2023; Kozcu Cakir et al., 2021). In an educational context, AR can be used to provide a more immersive and concrete learning experience, especially in technical subjects such as Computer Systems.

With AR, students can see and interact directly with virtual representations of computer components or network simulations projected onto the real world. For example, students can visualize a three-dimensional model of a motherboard and learn more about its functions more understandably. They can "disassemble" and "install" virtual components without the need for physical hardware, which of course can reduce the cost and risk of damage to real hardware.

In supporting the development of quality vocational education, the Indonesian government has issued various regulations that underlie the importance of vocational education and innovation in learning methods. One relevant legal basis is Law Number 20 of 2003 concerning the National Education System, which states that vocational education is part of the national education system that aims to prepare students to become professional workers in certain fields. Article 15 of the Law emphasizes that vocational education aims to prepare students directly to enter the world of work.

Furthermore, Law Number 12 of 2012 concerning Higher Education also mentions the importance of developing an education curriculum that is responsive to the needs of the labor market, which is certainly relevant to the context of vocational education. Vocational education in vocational schools is required to be able to produce graduates who are ready to enter the workforce with adequate skills according to industry needs.

In addition, Presidential Regulation Number 8 of 2012 concerning the Indonesian National Qualification Framework (KKNI) emphasizes the importance of achieving the expected competencies of vocational education graduates. This regulation serves as a reference for educational institutions, including vocational schools, in compiling a curriculum that emphasizes practical skills and technical understanding needed in the industrial world. KKNI also directs vocational education to be more adaptive to technological developments and changes in industrial needs.

To further support the improvement of the quality of vocational education, the Ministry of Education and Culture also issued Regulation of the Minister of Education and Culture Number 34 of 2018 concerning National Standards for Vocational Education. This regulation regulates various aspects related to vocational education in Indonesia, including the development of a curriculum that focuses on work skills, as well as the implementation of project-based learning and simulations that are relevant to the demands of the industrial world. In this case, the development of technology-based learning media such as AR is in line with this policy because it can help improve students' technical skills and provide a more relevant and applicable learning experience.

Regulation of the Minister of Education and Culture Number 50 of 2020 concerning Vocational Secondary Education also emphasizes the importance of innovation in learning methods. This regulation emphasizes that learning in vocational schools must be able to respond to the needs of Industry 4.0, which is driven by the development of digital technology, including the Internet of Things. Things (IoT), big data, and AR. AR technology, in this case, can be one of the relevant media in developing the competencies of vocational school students, especially in the field of Information and Communication Technology (ICT) such as Computer Systems.With this background, the development of Augmented reality-based learning media is becoming increasingly relevant and important in improving the quality of vocational education in vocational schools, especially in Computer Systems subjects. AR not only provides a more realistic and immersive visual representation but also allows students to learn more interactively and practically.

Augmented technology Reality (AR) in learning Computer Systems subjects in vocational schools offers a few significant advantages. One of the main benefits is better visualization. With AR, students can see a three-dimensional representation of computer hardware components in depth and realistically. This technology allows for more detailed and accurate visualization so that students not only learn the components through two-dimensional images in textbooks but can see them from various angles and even manipulate these virtual objects. For example, students can better understand how a motherboard works by seeing it in 3D, where each component can be explored more clearly and realistically.

In addition, AR also supports direct interaction between students and the virtual simulations displayed. In Computer Systems learning, students can use AR to learn how computer components work, such as processors, RAM, or hard drives, without having to hold the physical device. For example, they can practice how to assemble a computer virtually, design a computer network, or understand the flow of data in a system. This certainly provides a more in-depth learning experience because students can interact with the material they are learning, not just observe or imagine the concepts.

Another advantage of AR is its ability to support self-paced learning. This technology gives students the flexibility to learn at a pace that suits their abilities and speed. They can repeat virtual simulations or experiments without time constraints, giving them the freedom to study the material until they truly understand it. For students who may take longer to grasp a particular concept, AR provides an opportunity for independent, in-depth learning without the pressure of limited classroom time.

Finally, the use of AR in Computer Systems learning also contributes to reducing costs and risks. One of the obstacles that schools often face, especially in vocational education, is the high cost of providing adequate physical equipment such as computers, servers, or network components. With AR, schools can reduce the need for expensive and vulnerable physical hardware. Students can use virtual hardware simulations provided by AR to practice assembling computers or building networks without worrying about the risk of device damage or repair costs. This not only saves costs but also allows more students to learn directly through interactive and safe simulations.

Overall, the application of AR in Computer Systems learning in vocational schools offers an innovative and effective solution to overcome various challenges often faced in technical learning. With better visualization, direct interaction, more flexible self-learning, and reduced costs and risks, AR can help improve the quality of learning and provide a more engaging and immersive learning experience for students. The use of AR in Computer System learning at SMK Negeri 2 Argamakmur is expected to help students understand complex materials more enjoyably and efficiently. Students do not only learn from static text or images but can see and interact with virtual simulations of the computer components they are studying. Thus, AR can be an effective solution in overcoming the limitations of conventional learning methods and helping prepare vocational school students to be better prepared to face the demands of the world of work that increasingly prioritizes technology.

To improve the quality of vocational education, innovation in learning methods is a must. The use of Augmented Learning technology Reality (AR) in Computer Systems subjects is one form of innovation that can help vocational school students understand abstract technical concepts more deeply and practically. Along with the support of various educational regulations issued by the government, the development of AR-based learning media is expected to provide a significant contribution to improving the competence of vocational school graduates, especially in facing the increasingly complex and high-tech industrial era 4.0.

Augmented-based learning media Reality (AR) has gained widespread attention in education due to its ability to significantly enhance the learning experience. The technology offers a new way to present abstract and complex subject matter by incorporating virtual elements into the real world. Several experts have expressed their views on AR's potential to enhance educational effectiveness, especially in subjects that require interactive visualization, such as Computer Systems.

Azuma (1997) defines AR as a technology that allows the integration of virtual objects with the real world in real-time. He emphasized that AR has great potential in education because it can create a more realistic and contextual learning experience. This is especially important in subjects that require an understanding of abstract physical objects, such as computer components and networks. AR can provide 3D visualizations that allow students to directly understand how hardware works, which would be difficult to achieve through conventional learning methods such as textbooks.

Billinghurst and Kato (2002) support this statement by adding that AR can increase student engagement in learning. They state that AR allows for interactive 3D content delivery, which can overcome the limitations of

visualization in difficult-to-understand materials. In the context of Computer Systems courses, visualization of hardware components and how they work becomes more understandable to students through the use of AR. In addition, students can interact directly with virtual objects, which strengthens their understanding of abstract technical concepts.

Shelton and Hedley (2004) argue that the use of AR in education provides opportunities for more active and collaborative learning. AR allows students to interact with digital objects, which not only enhances conceptual understanding but also promotes critical thinking skills and further exploration. In Computer Systems learning, students can explore how hardware and software systems interact in a safe and structured environment, giving them the freedom to try and understand the concepts independently.

Wu et al. (2013) found that one of the main advantages of AR is its ability to increase students' learning motivation. The interactive nature of AR makes learning more interesting, so students are more motivated to learn the material given. Students who use AR show a higher interest in the material being studied, and this can help improve their overall learning outcomes.

According to Ibáñez et al. (2014), AR is very useful in helping students understand complex material. In Computer Systems subjects, students are often faced with various technical concepts that are difficult to understand only through text or static images. AR can present dynamic and interactive visual representations, helping students understand how hardware components function and how they interact with each other in a computer system.

Chang et al. (2014) also stated that AR can enrich students' learning experience by presenting simulations that are close to real conditions. In Computer Systems learning, this simulation can be used to show how various computer components, such as the motherboard, CPU, and RAM, work together. By using AR, students can visualize how the computer system architecture is structured and how each component is interconnected.

Read et al. (2014) reviewed the literature related to the use of AR in education and concluded that this technology has great potential to improve learning outcomes. Especially in terms of student engagement and conceptual understanding, AR has been shown to make the learning process more effective and enjoyable. In the Computer Systems subject, AR allows for deeper visualization of hardware, which makes it easier for students to understand the material.

According to Hruby (2016), the integration of AR in vocational education curricula such as in SMK is very important. AR can bridge the gap between theory and practice, especially in technical subjects such as Computer Systems. Using AR, students can gain a better understanding of technical components and how they function, allowing them to be better prepared for challenges in the workplace.

Santos et al. (2016) showed that students who used AR in learning showed a significant increase in understanding compared to traditional learning methods. The visual representation offered by AR makes difficult concepts easier to understand. In the context of Computer Systems subjects, AR can provide direct visualization of how various

elements in a computer system function, which helps students understand the concepts better.

Akçayır and Akçayır (2017) highlighted that one of the main advantages of AR is its ability to enhance interaction and collaboration between students. The use of AR not only encourages students to interact with virtual objects but also encourages discussion and collaboration among students. This is especially important in Computer Systems learning, where students often need to work together to solve complex technical problems.

Cheng and Tsai (2019) argue that AR helps students connect abstract knowledge with the real world. With AR, students can see firsthand how the technical components of a computer system work, which strengthens their understanding of these technical concepts. This is especially important in vocational education, where students need to understand how theory is applied in practical situations.

Yilmaz et al. (2020) found that AR not only improves students' cognitive understanding but also increases emotional engagement in learning. Students feel more enthusiastic and engaged when using AR to learn difficult concepts, such as computer systems. This shows that AR can create a more enjoyable and effective learning experience.

Zhao et al. (2020) emphasized the importance of using AR learning media in engineering and vocational education. They stated that AR can help reduce the gap between theory and practice, which is often a challenge in engineering learning. With AR, students can see how technical concepts are applied in the real world, which helps them better understand the material.

Cuckoo et al. (2021) stated that the use of AR in education resulted in significant improvements in students' practical skills. In the Computer Systems subject, AR allows students to visualize and understand the physical components of a computer, which is important for improving their technical skills.

Kim et al. (2021) emphasized that AR can present materials that are tailored to the student's learning pace. With AR, students can learn materials at their own pace, which gives them more flexibility in understanding difficult materials. In the context of vocational education, this helps students to better understand the technical concepts taught.

Method

This research adopts the Research method and Development (R&D) with the main objective of developing Augmented reality-based learning media Reality (AR) for Computer Systems subjects at State Vocational School 2 Argamakmur.

The R&D method was chosen because it is suitable for creating, testing, and evaluating new, innovative learning products. The development model used is the ADDIE model, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation. The following is a detailed explanation of each stage and how this

research was implemented (see Figure 1).

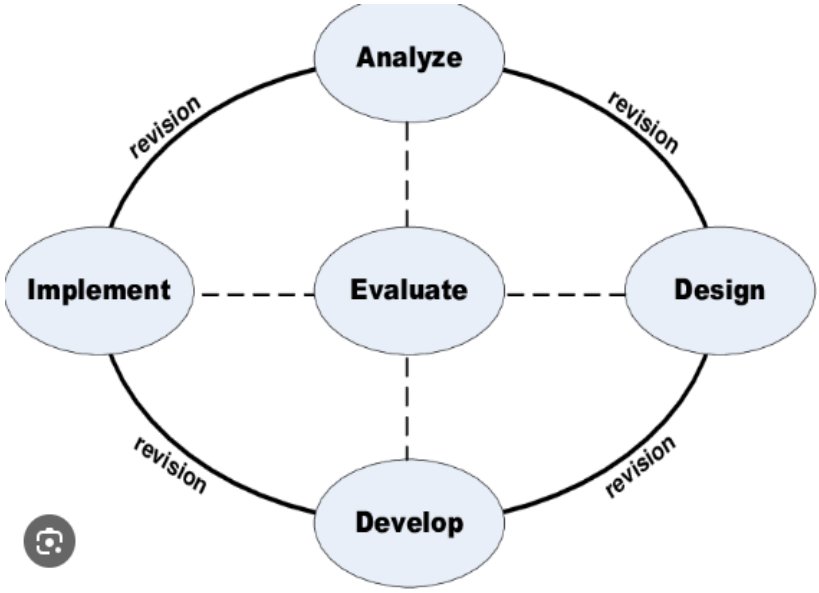

Figure 1. ADDIE Model

In the analysis stage, this study began with the identification of needs and problems faced in learning Computer Systems at SMK Negeri 2 Argamakmur. This analysis involved collecting initial data through classroom observations, interviews with teachers, and literature studies related to conventional learning methods and the application of AR technology in education. From this analysis, it was identified that conventional methods were less effective in conveying abstract concepts such as computer architecture and network systems.

The design stage focuses on designing AR-based learning media to be developed. At this stage, the research team designs storyboards, interaction scenarios, and content to be included in the AR application. The design of learning media includes three-dimensional visualization of computer components, network simulations, and intuitive user interactions. This design is carried out based on the results of needs analysis and input from material experts and media experts to ensure the suitability of the content and user interface.

In the development stage, the AR learning media that has been designed is implemented in the form of a prototype. This process involves creating AR applications using special software and development tools. This learning media is tested internally by the development team to ensure functionality and technical quality. The development also includes the integration of interactive elements that allow students to interact with 3D models of computer components and network simulations.

After the prototype of the learning media was completed, the implementation stage was carried out by involving research subjects. The research subjects consisted of 30 students of grade XI at SMK Negeri 2 Argamakmur. AR learning media was implemented in several learning sessions to replace conventional learning methods that are commonly used. During the implementation, students used AR media to learn various concepts in the Computer Systems subject. The use of this media was monitored periodically to evaluate student responses and its

effectiveness in improving understanding of the material.

The evaluation stage is carried out to assess the effectiveness and feasibility of the AR learning media that has been developed. This evaluation includes several components:

- Media Eligibility Test: AR learning media is evaluated by subject matter experts and media experts. Subject matter expert validation ensures that the content presented is by applicable curriculum and academic standards, while media expert validation assesses the technical quality, user interface, and interactivity of the AR application.
- Limited Trial: AR media was also tested on a limited basis involving a group of students from class XI at SMK Negeri 2 Argamakmur. This trial aims to collect feedback from students regarding the use of media, level of difficulty, and comfort of interaction.

Data Collection

Data was collected using several instruments, namely:

- Questionnaire: A questionnaire was distributed to students and teachers to measure their responses to the AR learning media. The questionnaire included questions regarding student engagement, ease of use, and the media's impact on understanding the material.
- Test: The test was conducted to assess the improvement in students' conceptual understanding before and after the use of AR media. This test was designed to measure the extent to which AR learning media was successful in improving students' understanding of the material being taught.

Results

This study aims to assess the effectiveness and feasibility of Augmented reality-based learning media. Reality (AR) for Computer Systems subjects at SMK Negeri 2 Argamakmur. The research was conducted by applying the ADDIE model which includes analysis, design, development, implementation, and evaluation.

Expert Feasibility Assessment

Augmented-based learning media Reality (AR) is carried out by two leading experts, namely material experts and media experts. This assessment aims to ensure that the learning media developed is not only relevant in terms of content but also effective in terms of design and implementation.

Assessment by Subject Matter Experts

Material experts gave a very positive assessment of this AR-based learning media, with a score reaching 88.5%. This score shows that this media is very suitable for use in the context of learning because its content is accurate and relevant. Material experts assessed that this media succeeded in presenting material in an informative way and accordance with the applicable curriculum, thus supporting the student learning process effectively.

Assessment by Media Experts

On the other hand, media experts also gave a very satisfactory assessment, with a score of 91.2%. This score reflects that AR-based learning media meets high standards in terms of design and implementation. Media experts assessed that the interface design and interactivity of this media were very good, as well as its smooth and user-friendly implementation. This ensures that the learning media is not only attractive but also easy to use by students. The assessment results from both experts show that this AR-based learning media gets a very satisfactory score in terms of content and design. With a score of 88.5% from material experts and 91.2% from media experts, it can be concluded that this learning media is very suitable for use and meets the eligibility standards needed to support the teaching and learning process effectively.

Testing Effectiveness

Augmented Learning Media Reality (AR), we conducted a study involving pre- and post-lesson tests to measure students' understanding of the material taught. This study aims to determine the extent to which the use of AR media can affect student learning outcomes.

In the initial stage of the study, students underwent a pre-lesson test to evaluate their level of understanding before introducing AR media. The results of this test showed an average score of 65.3. This test serves as an initial benchmark of students' knowledge before they engage with AR-based learning media.

After the learning session using AR media, students then took a post-lesson test. The results of this test showed an increase in the average score to 82.7. In other words, after the use of AR media, there was a significant increase in students' understanding of the material taught.

This increase in value reflects an increase of 26.5% compared to the average pre-test value. This data confirms that AR-based learning media is effective in improving student understanding. The results of this study indicate that AR media not only makes learning more interactive and interesting but can also significantly improve student learning outcomes, making it a valuable tool in the educational process.

Student Response

Augmented Learning Media Reality (AR) through pre- and post-lesson tests, we also assess the level of student satisfaction with the use of this media. The purpose of this assessment is to gain deeper insight into how students respond and feel about the learning media applied.For that, we conducted a student satisfaction survey after they were involved in learning using AR media. This survey was designed to assess the extent to which students felt satisfied and interested in the media used during the learning process.

The survey results showed that 89.4% of students responded positively to the use of AR-based learning media. This figure illustrates that the majority of students are satisfied with their learning experience and show high

interest in the media. This satisfaction not only reflects a fun learning experience but also confirms that AR media can meet student expectations in terms of interactivity and engagement.

Overall, the results of this test and survey underline that AR-based learning media is not only effective in improving understanding of the material but also successfully attracts interest and increases student satisfaction. This media offers an innovative and fun learning approach, thus providing a positive impact both in terms of learning outcomes and student experience. The results of the expert feasibility evaluation, increased student understanding, and positive responses from students, it can be concluded that the AR-based learning media developed is effective in improving student understanding and is very suitable for use as a learning medium in the Computer Systems subject at SMK Negeri 2 Argamakmur. This media not only meets high feasibility standards but also has a significant positive impact on student learning outcomes.

Conclusion

Augmented Reality-based learning media Reality (AR) shows very positive results in the context of education. The assessment of this learning media by material experts and media experts reflects its high quality, with scores of 88.5% and 91.2% respectively, indicating that this media is considered "very feasible." In addition, testing the effectiveness of AR media on student understanding showed significant results. The average pre-test score before using AR media was 65.3, while the average post-test score after using AR media increased to 82.7, increasing by 26.5%. This increase confirms that AR media is effective in improving student learning outcomes.

Responses to AR-based learning media were also very positive. Student satisfaction surveys showed that 89.4% of students were satisfied and interested in the media used, describing a satisfying and interesting learning experience. Taking into account the assessment of material and media experts, significant improvements in learning outcomes, and high levels of student satisfaction, it can be concluded that the AR-based learning media developed has proven effective in improving student understanding. Therefore, this media is suitable for use as a learning tool in the Computer Systems subject at SMK Negeri 2 Argamakmur.

Recommendations

The rapid development of technology has revolutionized various fields, including education. In today's digital era, the integration of advanced technology into the learning process is becoming more essential to enhance students' comprehension and engagement. One such innovation is the use of Augmented Reality (AR) in learning media. AR combines real-world environments with digital elements, allowing students to visualize complex concepts in an interactive and immersive way. This proposal recommends the adoption of Augmented Reality-based learning media for the Computer Systems subject at SMK Negeri 2 Argamakmur.

Challenges in Teaching Computer Systems

The subject of Computer Systems covers a broad range of topics, such as hardware components, software

architecture, networking, and system operations. These topics are often theoretical and abstract, making it difficult for students to fully grasp the underlying concepts through traditional methods of learning, such as textbooks and lectures. Moreover, practical exercises in laboratories sometimes cannot fully represent real-world scenarios, and limited resources may hinder students from accessing high-quality, interactive learning experiences. As a result, students may face challenges in understanding complex topics such as motherboard architecture, CPU processing, and data flow in networks.

The Role of Augmented Reality in Enhancing Learning

Augmented Reality (AR) technology provides an innovative solution to these challenges. AR allows students to visualize and interact with 3D models of computer components, operating systems, and networks, bringing abstract concepts to life. By using AR, students can explore hardware systems virtually, rotate and inspect 3D models, and understand the relationships between components in a highly interactive environment.

For example, students can use their smartphones or tablets to scan images of hardware components, which will then display a 3D model of the component in AR. They can explore the inner workings of a CPU, observe data pathways on the motherboard, or even simulate network topologies.

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