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Review Article

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Application of Augmented Reality-Based Learning Technology to Information Processing and Memory in Vocational High Schools: A Literature Review

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Abstract

This study explores the benefits and challenges of implementing Augmented Reality (AR) technology to enhance learning effectiveness in Vocational High Schools (SMKs), particularly in improving students' memory and understanding of technical concepts. Through a literature review, this research focuses on studies involving SMK students as the primary participants, with teachers providing additional insights to assess the readiness and impact of AR in vocational education. AR technology offers interactive, three-dimensional simulations in real-world environments, such as workplaces, allowing students to develop technical skills in a practical, safe, and immersive setting. In vocational education, AR has been found to improve students' memory retention and conceptual comprehension, helping them grasp complex information and technical procedures necessary for fields like automotive, welding, and machining. This technology effectively overcomes the limitations of traditional learning methods, which often struggle to represent abstract concepts visually. Despite these advantages, the implementation of AR in SMKs faces significant challenges. Key obstacles include limited budgets, inadequate infrastructure, and a lack of technical expertise among educators. The high costs associated with AR hardware and software remain a barrier for many SMKs, particularly in Indonesia. Also, successful integration of AR requires extensive teacher training to ensure effective use of the technology in the curriculum. The literature review identifies the benefits of AR, the challenges involved, and potential solutions for its successful implementation. The findings are intended to guide educational institutions and policymakers in developing effective, efficient, and sustainable strategies for incorporating AR into vocational high schools.

1. Introduction

Vocational High School (SMK) education is one of the levels of education that aims to produce graduates who have vocational competencies in accordance with their fields of expertise and are ready to enter the world of work. However, vocational school graduates are the level of education that has the highest unemployment rate, reaching 9.31% (Badan Pusat Statistik, 2024). This reflects the gap between the competence of graduates and the needs of the industrial world. In addition, the quality of vocational education in general is still uneven, with many schools facing limited infrastructure, inadequate practical facilities, and lack of access to the latest industrial technology. According to Khurniawan et al. (2021), vocational schools have the lowest quality of education compared to other levels of education, with a good quality index of 12%. Meanwhile, when viewed based on school accreditation scores, 27.53% of vocational schools in Indonesia have good accreditation (accreditation B), and 21.89% of vocational schools have a very good rating (accreditation A). Vocational schools in Indonesia face high operational challenges, especially in providing practice facilities that are adequate and relevant to industry needs. Vocational schools have high

operational costs to be able to provide optimal education (Majid & Khurniawan, 2019). This condition has an impact on the quality of learning because the limitations of tools prevent students from getting optimal practical experience. Technology-based innovations and learning strategies are needed to improve the quality of graduates and reduce the unemployment rate, one of which is by applying Augmented Reality (AR) technology in the learning process (Aryawan, 2023).

The integration of Augmented Reality (AR) technology in vocational education addresses the challenges posed by high operational costs and limited access to physical equipment. AR provides innovative solutions that enhance the learning experience by allowing learners to engage in interactive simulations, thereby improving their understanding of technical skills without the need for operational and costly materials. AR reduces the need for physical equipment, significantly lowering operational costs for vocational schools (Sahria et al., 2024). AR is also a solution for vocational education, allowing students to interact with 3D interior design materials without the need for expensive physical equipment, thereby enhancing the learning experience while addressing operational cost challenges in vocational schools. (Sahria et.al., 2024).

Augmented reality (AR) significantly improves student engagement and understanding of learning. Studies show that AR increases student motivation and engagement, with 92.5% of students reporting positive experiences in productive mechanical engineering subjects (Satria et al., 2023). Augmented Reality (AR) can improve vocational education by providing interactive simulations, reducing the need for expensive physical equipment, and increasing student motivation and understanding, thereby addressing the operational cost challenges faced by vocational schools. AR facilitates hands-on learning, allowing students to visualize and manipulate 3D models, which improves knowledge of technical concepts (Efendi et al., 2022).

The application of *Flipbooks* with Augmented Reality (AR) in vocational schools significantly improves students' critical thinking skills, provides interactive learning experiences that align with the demands of Society 5.0 and enhances comprehension through multisensory engagement. (Sabitri et.al., 2024). AR technology allows learners to understand complex and abstract concepts through 3D simulation and visualization, which directly aids in information processing memory. With AR, learners can learn the working process of machines or welding techniques through virtual objects that are integrated with the real world, allowing them to observe the steps of operation in a safe environment. This not only improves memory but also increases students' understanding of the theories that are implemented in practice (Akçayır & Akçayır, 2017).

In traditional learning, abstract concepts are often difficult to fully understand without clear visualization, especially for vocational learners who have many practical approaches in the field. AR technology allows learners to learn technical skills through interactive simulations without the need for expensive physical equipment. For example, AR can be used to simulate the welding or machine assembly process so that learners still get a realistic and safe learning experience at a lower cost (Garzón & Acevedo, 2019). Vocational education, especially in Vocational High Schools (SMK), faces the challenge of providing learning that is not only based on theory but also practice so that students have technical competencies that are in accordance with the needs of the world of work.

In this context, augmented reality (AR) technology is an innovation that improves the quality of learning. AR enables the integration of visual, auditory, and kinesthetic elements, providing an interactive learning experience through virtual objects presented in a real environment. This technology is relevant to the theory of information processing (Atkinson & Shiffrin, 1968) in Wixted (2024), which states that learning involving various sensory channels can improve memory retention and conceptual understanding. This theory argues that effective learning occurs when information is processed through several stages, from sensory input to long-term memory, facilitated by the technology that supports this process. Within this theoretical framework, AR supports learning in vocational schools by making it easier for students to process complex technical information through visual simulations and practical manipulation. In welding training, AR can provide *real-time visual guidance*, helping students understand complex processes and techniques more effectively (Agrawal & Pillai, 2020).

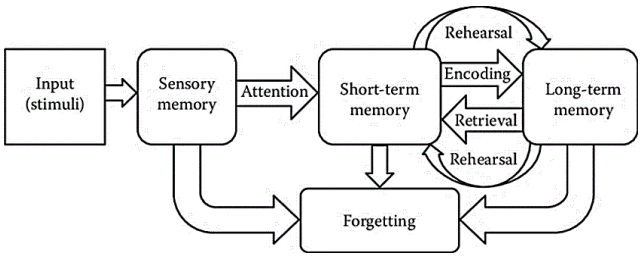

Figure 1. Atkinson & Shiffrin memory model.
Source: Atkinson & Shiffrin (1968)

Figure 1 shows that information processing through various sensory channels can improve memory retention. The use of AR in vocational high schools improves students' competence and memory by visualizing the 3D welding process, facilitating interactive learning, and providing engaging experiences that improve understanding and retention of information related to practical skills in welding (Solikhatun et al., 2021). AR enhances learning by improving visualization and engagement, which can significantly improve competency and memory retention in vocational training,

including processes such as welding, through the delivery of interactive, focused information in the real workplace. In addition, AR technology is possible to provide an excellent and repeatable learning experience to improve long-term understanding of concepts as well as improve students' technical skills. AR also supports Edgar Dale's theory of the cone principle of experience by providing a simulated experience that is close to real experience.

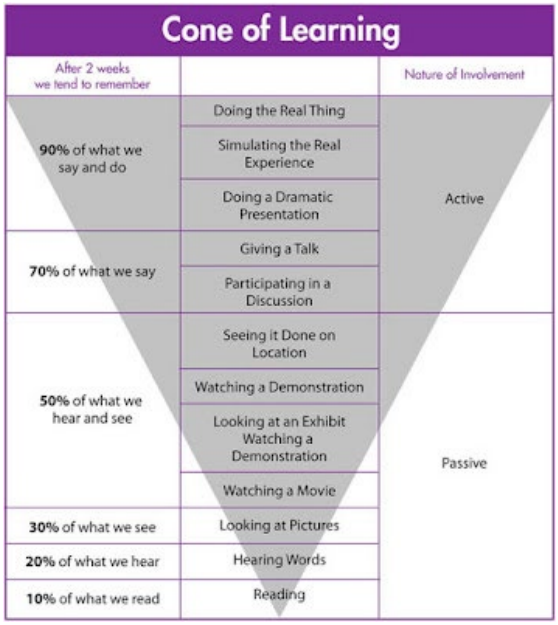

Figure 2. Edgar Dale's Learning Experience Cone
Source: Prismanata (2021)

The AR on Edgar Dale Learning Experience Cone provides a simulated experience that is close to a real experience. Edgar Dale describes the benefits in his empirical cone, where direct or simulated experience has the greatest impact on information retention. AR, as a modern learning medium, offers experiences equivalent to "doing the real thing" and simulated experiences, thus supporting the mastery of students' technical skills. Based on the Learning Experience Cone, AR provides active learning to students in real-world situations. The learning experience of AR as a learning medium is approximately 90% because AR is a simulation of experiences like in the real world. The percentage is how much material or learning experience students can remember.

In addition, AR can help vocational schools overcome high operational constraints. With AR simulations, learners can practice technical skills without the need for expensive real resources, such as engines or fuel. This not only reduces operational costs but also creates a safe and environmentally friendly learning environment. By integrating AR, vocational schools can provide efficient and effective practice-based learning, albeit with budget constraints. However, AR investment in vocational education in vocational schools is very high. Starting from the fulfillment of infrastructure, limited teacher proficiency and curriculum integration that is not in accordance with the world of work. To overcome this obstacle, a strategic approach is needed so that the implementation of AR can be adjusted to the needs and conditions of the school. Thus, this research is expected to provide an overview of how AR can be effectively applied in vocational schools, as well as solutions that allow this technology to be more widely accessible in schools with limited budgets.

This study aims to review the benefits, challenges, and strategies of AR implementation in improving learning in vocational schools through a literature review. The research questions from this literature study are:

1. How can Augmented Reality (AR) technology improve students' memory, information processing, and understanding of technical concepts in Vocational High Schools (SMK)?
2. What are the main challenges faced in the implementation of AR technology in vocational schools?
3. What are the strategies to overcome obstacles in the implementation of AR in vocational schools?

The application of AR in vocational schools offers innovative solutions to improve the quality of vocational learning. Integrating the principles of information processing theory and the benefits of learning media, according to Edgar Dale, is supported by the latest research. This study was conducted to collect data on the application of AR, which has great potential to support the mastery of skills of vocational school students while answering the challenge of limited operational costs. Thus, AR can be a strategic step to increase the relevance of vocational school graduates in the world of work.

2. Materials and Methods

This study employs a qualitative descriptive research design, utilizing a literature review approach to investigate the application of Augmented Reality (AR) learning technology in Vocational High Schools (SMKs). The research process involved several stages: (1) study development, (2) implementation of the review, (3) summarization of findings, and (4) reporting the review results. This structured approach is particularly beneficial for tracing the progression and development of specific academic fields over time (Snyder, 2019). The literature review process in this study involved collecting bibliographic sources, critically analyzing the relevant research materials, and annotating them for further evaluation. This method enabled a comprehensive understanding of the topic through systematic exploration of existing studies.

The content analysis methodology was employed to systematically evaluate the collected materials. Content

analysis is an objective and scientific method that focuses on analyzing the content or messages within texts, films, media articles, and historical documents (Roller, 2019). The purpose of this approach was to gain in-depth and unbiased insights into how Augmented Reality is applied in vocational education, particularly in improving learning outcomes in SMKs. The content analysis process is aimed at identifying trends, themes, and patterns across the selected studies, which were then synthesized to form a coherent narrative on the effectiveness of AR in vocational learning.

The research was conducted between October and November 2024, with a focus on studies published between 2018 and 2024. The inclusion criteria for the literature reviewed required that the studies be published in peer-reviewed journals, either internationally or nationally accredited. Additionally, the research was required to focus specifically on the application of AR learning technology in vocational schools, ensuring relevance to the context of this study. By selecting only research articles that met these criteria, the study ensured the inclusion of high-quality, up-to-date literature on the subject matter.

This research applied a rigorous and systematic literature review process, coupled with content analysis, to provide an in-depth evaluation of the current state of AR learning technology in Vocational High Schools. The findings aim to contribute valuable insights into the effectiveness, challenges, and potential solutions for integrating AR into vocational education.

3. Results

The following is an analysis of several scholarly articles on the application of Augmented Reality (AR) in learning at Vocational High Schools (SMKs).

Table 1. Augmented Reality (AR) Application Analysis

No.	Author(s) and Year(s)	Research Title	Research Findings
1	Efendi, A., Wihidayat, E. S., Basori, B., & Maryono, D. (2022)	Empowerment of Vocational Teachers Through the Development of Learning Media Based on Augmented Reality Media Applications.	1. Augmented Reality (AR) enhances the vocational school learning experience. 2. Training fosters innovative and creative teaching methods for teachers. 3. AR applications make learning more engaging for students. 4. AR improves student engagement and learning outcomes. • Vocational schoolteachers achieved 85.6% competence in training.
2	Garzón, J., & Acevedo, J. (2019)	Meta-analysis of the Impact of Augmented Reality on Students' Learning Gains.	1. AR has a moderate effect on improving learning outcomes. 2. AR enhances understanding of abstract concepts in education. 3. The learning environment moderates the impact of AR. • Findings guide the future development of AR applications for educational settings.
3	Sahria, Y., Santoso, B., & Kuat, T. (2024)	Innovative Learning Media for Interior Design Using Augmented Reality at Vocational High Schools.	1. AR enhances hands-on experience for vocational students. 2. AR integrates well with real-world environments. 3. Student feedback indicates that the app is engaging and interactive. • The app is compatible with a wide range of Android smartphone specifications.
4	Satria, L., Primawati, P., Purwantono, P., & Prasetya, F. (2023)	Implementation of Augmented Reality in the Basic Work Subject of Mechanical Engineering at SMK Negeri 1 West Sumatra.	1. The study examines AR's impact on students' perceptions of learning. 2. Positive response to AR, with a satisfaction score of 92.5%. 3. AR increases interest, engagement, and understanding of technical concepts. 4. Research contributes to the improvement of learning strategies and experiences. 5. Challenges include device limitations and the need for teacher training. • Findings support the integration of AR into vocational education strategies.
5	Solikhatun, I., Widodo, A. W., & Maslahah, S. (2021)	The Potential of Augmented Reality for Vocational High	1. AR combines digital and real-world learning experiences.

		School Learning Amid Covid-19 Spread.	2. AR enhances students' understanding of materials. 3. AR improves memory retention through engaging experiences. 4. AR improves practical learning and boosts student motivation. • The study highlights reduced costs and improved learning outcomes.
6	Kusandi, M. (2024)	Strategies for the Use of Augmented Reality Technology in Learning.	1. AR enhances the vocational school learning experience. 2. Main barriers include infrastructure and teacher understanding. 3. Effective strategies involve curriculum development and teacher training. 4. Investment in infrastructure is crucial for AR implementation. 5. AR enhances student engagement and industry-relevant skills. • Cross-sector collaboration is enhancing AR application in education.
7	Arief, U., Wibawanto, H., & Nastiti, A. (2018)	Augmented Reality Technology for Vocational Education in the Disruption Era.	1. AR enhances the vocational education learning experience. 2. AR improves the overall learning experience. 3. Usability indicators show high satisfaction and ease of use. 4. AR reduces costs by utilizing virtual materials for training. • AR can be used anytime and anywhere for learning.
8	Herlandy, P. B., Azim, F., & Majid, N. W. A. (2020)	The Effectiveness of Augmented Reality-Based Learning on Vocational Competencies of Vocational School Students.	1. AR-based media effectively improves vocational competencies. 2. AR media significantly enhances learning outcomes in computer networks. • AR-based media can be tailored to meet the needs of vocational curricula.

Table 1 indicates that the research findings consistently highlight the significant benefits of Augmented Reality (AR) in enhancing vocational education. AR has been shown to improve learning outcomes by providing students with immersive, interactive experiences that make abstract concepts more tangible. For instance, Garzón and Acevedo (2019) found that AR has a moderate effect on improving learning outcomes, particularly in terms of understanding complex concepts. In mechanical engineering, Satria et al. (2023) reported that AR significantly increased student interest and engagement, leading to a deeper understanding of technical concepts. Moreover, AR enhances students' memory retention and practical learning, which boosts motivation and overall academic performance, as noted by Solikhatun et al. (2021). This interactive learning environment is particularly beneficial in vocational education, where hands-on experience is essential.

The use of AR also fosters greater student engagement. Studies by Efendi et al. (2022) and Satria et al. (2023) demonstrated that AR applications made learning more engaging and enjoyable, with students reporting high satisfaction levels. This increased engagement is crucial in vocational settings, where practical skills are developed through active participation. Additionally, the ability to interact with 3D models and simulations helps students better grasp abstract concepts, a finding emphasized by Garzón and Acevedo (2019), who noted that AR enhances the understanding of difficult topics in education.

However, the implementation of AR in vocational schools faces several challenges, particularly in terms of infrastructure and teacher readiness. Kusandi (2024) identified limited infrastructure and a lack of AR-compatible devices as significant barriers to widespread adoption. Furthermore, Efendi et al. (2022) highlighted the importance of teacher training, as AR integration requires educators to develop innovative and creative teaching methods. Training programs that help teachers gain competence in using AR technology are critical for its successful implementation. Teachers who participated in AR training achieved a competence rate of 85.6%, indicating the importance of preparing instructors for the effective use of this technology.

Cost is another consideration, with the initial expense of AR hardware and software potentially limiting its adoption, especially in resource-constrained schools. However, as Arief et al. (2018) pointed out, AR could offer cost-saving benefits by reducing the need for physical materials and resources, making it a potentially cost-effective solution in the long run.

Overall, while there are challenges in terms of infrastructure, costs, and teacher training, the integration of AR in vocational education presents substantial benefits. It enhances student engagement, improves learning outcomes, and provides an effective means of teaching complex concepts. Addressing these challenges through investment in infrastructure and teacher development will be key to fully realizing the potential of AR in vocational schools.

4. Discussion

The integration of Augmented Reality (AR) technology in Vocational High Schools (SMK) has shown significant potential in enhancing the learning process, particularly in terms of improving teaching effectiveness, strengthening memory retention, and increasing graduates' competencies. However, its implementation faces several challenges that need strategic approaches to overcome. This discussion will explore the benefits, challenges, and strategies for the development of AR technology in vocational schools.

4.1. Benefits of AR Implementation in Vocational Schools

AR offers a highly engaging and interactive learning experience, making it particularly suitable for vocational school students, whose education is centered on practical, technical skills. One of the main advantages of AR is its ability to visualize complex technical concepts, such as mechanical mechanics, electricity, and welding, in three-dimensional formats. These concepts, often difficult to grasp through theoretical explanations alone, become more understandable when visualized interactively. For instance, AR enables students to simulate real-world scenarios before using actual equipment, which allows for a safer, risk-free learning environment. AR-based e-modules, which incorporate 3D objects and multimedia elements, have proven to be effective in helping students gain a deeper understanding of the material (Trinoviora, 2024). Furthermore, AR enhances the comprehension of abstract educational concepts (Garzón & Acevedo, 2019).

The interactive nature of AR engages multiple forms of memory—visual, auditory, and kinesthetic—strengthening students' ability to retain information. By interacting with learning materials, students can more effectively transfer knowledge from short-term to long-term memory. For example, AR simulations in welding allow students to practice techniques in a virtual environment, mitigating the risk of accidents and providing a thorough understanding of the process before they engage with real equipment. AR also improves memory retention by offering an engaging and immersive experience (Solikhatun et al., 2021). This hands-on approach not only increases student engagement but also motivates them to participate actively in lessons, which contributes to improved learning outcomes. By making learning more enjoyable and relevant to real-world scenarios, AR helps students develop practical skills, enhances their motivation, and fosters a positive learning attitude (Supriyanto et al., 2023). Additionally, AR offers cost-saving advantages by replacing physical training materials with virtual simulations, which can be particularly beneficial for schools with limited budgets (Arief et al., 2018).

4.2. Challenges of AR Implementation in Vocational Schools

Despite its numerous advantages, the implementation of AR in vocational schools faces several challenges, particularly concerning technology, financing, and adaptation to local contexts. One of the major challenges is the cost of AR hardware and software, which can be prohibitively expensive. Vocational schools often have limited budgets and are unable to allocate sufficient funds for the purchase of AR devices, especially for specialized fields such as welding, where the cost of equipment can exceed one billion IDR per unit. Many schools also struggle to meet basic infrastructure needs, such as classroom facilities and stable internet access (Satria et al., 2023).

Additionally, the successful implementation of AR requires skilled personnel who can operate the technology and address potential software and hardware issues. Currently, the readiness of teachers to adopt AR technology remains low, as many educators lack the necessary technical skills to integrate AR into their teaching. Furthermore, students who are not familiar with digital technologies require special guidance to use AR effectively. Another challenge is that most AR content currently available is more generalized and does not specifically cater to vocational fields like automotive, welding, or machining, limiting its relevance to vocational students.

4.3. AR Implementation Development Strategy in Vocational Schools

To address these challenges and optimize the use of AR in vocational education, several strategies can be employed. First, partnerships with industry are essential for overcoming financial constraints. Industry collaborations can provide funding for AR devices and the development of AR content that aligns with the practical needs of the workforce. For instance, vocational schools in Indonesia have already begun to collaborate with technology companies to integrate AR into their curricula through programs like the Teaching Factory.

Second, integrated teacher internship training is vital to ensuring the successful implementation of AR. Teachers must undergo technical training to build the skills necessary to use AR in the classroom. One approach is to allow teachers to participate in internships

in industries that already utilize AR technology in their training programs.

Third, it is important to synchronize the industrial curriculum with AR content. The government, in collaboration with the industry and technology developers, should work together to create AR-based learning content that aligns with the vocational curriculum and meets the competency standards set by the National Professional Certification Agency (BNSP). For example, welding AR simulations should be designed according to these standards, ensuring their relevance and effectiveness.

Finally, government and industry support is crucial for the widespread adoption of AR in vocational schools. The government, in partnership with the industry, can offer financial assistance in the form of technology subsidies, infrastructure funding, and tax incentives to industries that contribute to the integration of AR into vocational education. This collaboration will help ensure schools have access to the necessary resources and support to implement AR effectively.

Thus, while the implementation of AR in vocational schools offers numerous benefits, it also presents significant challenges that require collaborative efforts and strategic planning. By leveraging industry partnerships, enhancing teacher training, aligning curriculum standards, and securing financial support, vocational schools can overcome these obstacles and fully realize the potential of AR in education.

5. Conclusions

This study concludes that the integration of Augmented Reality (AR) into vocational education within vocational schools offers substantial benefits, including enhanced learning effectiveness, improved memory for information processing, and increased student motivation through interactive learning experiences. AR enables learners to grasp complex technical concepts more efficiently, aligning with the practical needs of the workforce. However, challenges exist in its implementation, such as financial constraints, insufficient infrastructure, a shortage of skilled personnel, and the limited availability of AR content tailored to vocational curricula.

To fully realize the potential of AR, collaboration among government bodies, industries, and educational institutions is essential. This collaboration should focus on the provision of AR learning technologies, comprehensive teacher training programs, and the creation of relevant educational content. Addressing these challenges will enable AR to enhance student competencies and the relevance of vocational school graduates in the digital age. Additionally, further research is required to develop practical solutions that address the obstacles to AR adoption, including the creation of AR materials and technological support for vocational schools in line with their specific areas of expertise.

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