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Integrating Augmented Reality (AR) in Learning to Increase Student Engagement

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Abstract

The quality of education is largely determined by the level of active participation of students in the learning process. Unfortunately, many conventional teaching methods still rely on one-way delivery of material, which makes students less interested and have difficulty understanding the material thoroughly. To answer this challenge, Augmented Reality (AR) technology comes as an innovation that can create a more lively and interactive learning atmosphere. AR presents learning content in the form of three-dimensional visuals that can be seen and explored directly by students, so that learning becomes more fun, immersive, and easy to understand. This research examines how the use of AR can increase student engagement in the digital era through a qualitative approach by reviewing various studies and scientific literature. The results show that AR can increase learning motivation, concept understanding, and cooperation skills. AR is also flexible in adjusting students' diverse learning styles and supporting inclusive learning. However, AR implementation faces obstacles such as limited devices, infrastructure, and teacher readiness. Therefore, integrative strategies and support from various parties are needed so that the implementation of AR can run effectively and become a sustainable educational transformation tool.

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INTRODUCTION

Education is an important fundamental in creating superior and competitive human resources. In learning activities, the active involvement of students is very influential, because this not only has an impact on academic achievement, but also helps develop critical thinking, creativity, and the ability to work together which are essential competencies in today's modern era (Wahyuni et al., 2022; Wijaya et al., 2025). Student participation and engagement are key factors in improving learning effectiveness. Active student engagement can improve motivation, concept understanding and overall learning outcomes. Studies show that high student interaction and participation has a positive impact on academic motivation, learning performance and educational sustainability, making it important for educators to create a learning environment that encourages active student engagement (Lopez et al., 2025; Siregar, 2024; Hidayat et al., 2024). In addition, collaborative learning is also proven to improve students' social skills and knowledge through peer interaction (Mantri et al., 2022)(Aras et al., 2024).

Conventional learning methods are still widely used at various levels of education, but are often teacher-centered and lack technology integration. This causes low student participation, limited teaching aids, and lack of interactivity in the learning process (Sopandi, W., Sujana, A., Putri, F., & Kirana, 2025). As a result, students tend to be passive, less motivated, and have difficulty in understanding abstract concepts. The lack of innovation in teaching methods is also a challenge in creating an engaging and effective learning experience (Singh, J., , A., Parmar, R., & Ahmed, 2023). These conditions have the potential to reduce the quality of education and hinder the optimal development of student competencies.

Augmented reality (AR) technology offers innovative solutions to overcome the limitations of conventional learning. AR is able to create an immersive and interactive learning experience by incorporating virtual elements into the real environment, thus facilitating the visualization of abstract concepts and increasing student engagement (Ateş, 2024). The use of AR in learning is proven to increase student motivation, concept understanding, active participation, and learning outcomes compared to conventional methods (Silvester, S., & Suriyani, 2025). In addition, AR also supports collaborative learning and embodied learning, where students can interact directly with 3D objects physically and virtually, making the learning process more fun and meaningful (Mantri et al., 2022). Thus, the integration of AR in education has the potential to transform the learning process to be more effective, interactive, and relevant to the needs of students in the digital era.

Student participation and engagement in learning cannot be ignored, we can create a more interactive and engaging learning environment by identifying problems in conventional learning and utilizing the potential of AR technology. As stated in the research conducted by Charnila and Hakkun that Augmented Reality (AR) technology has an important role in encouraging student activeness and engagement during the learning process. By presenting a more immersive and interactive learning experience, AR helps students understand concepts more deeply. Based on the results of a systematic literature review, the use of AR is proven not only to make students more engaged, but also to hone thinking skills and increase engagement in practice-based learning activities. Not only that, AR also shows great potential in supporting the learning needs of students with special needs, making it an innovation that can improve the quality of education at various levels and fields, especially if implemented together with adequate teacher training and development of appropriate teaching materials (Heydemans, C. D., & Elmunsyah, 2024).

Other relevant research is research conducted by Anisyah, et al that the use of Augmented Reality (AR) media has a significant role in encouraging student participation and involvement during learning activities, because it is able to present an interactive and fun learning experience. The research findings show that AR is an effective learning tool, characterized by a considerable increase in learning outcomes with the average score of students increasing from 21.08 before learning to 70.60 after the use of AR. This innovative learning method is not only able to attract students' interest, but also create a more immersive learning atmosphere, thus making the learning process more lively and encouraging active involvement (Anisyah et al., 2024).

In research conducted by Nur Asitah, et al on how AR in learning media for two decades: trend analysis and mapping for future prospects states that the trend of using Augmented Reality (AR) in education is increasing, because it has proven effective as a learning tool. By providing a more interactive experience, AR can increase student engagement and understanding, making difficult concepts easier to grasp. This research highlights the important role of AR in learning media development and proposes a framework for managing knowledge in this area (Asitah et al., 2024).

Research conducted by Jumriani, et al on classroom management by applying AR applications in elementary schools explains that the application of Augmented Reality (AR) in learning increases student engagement and motivation by allowing direct interaction with virtual objects. This technology enriches the learning experience through visual and kinesthetic methods, making complex material more accessible. AR applications facilitate structured and engaging classroom management, encouraging a conducive learning environment. However, challenges such as limited technological infrastructure and the need for teacher training must be addressed to optimize the effectiveness of AR in basic education. Thus, further studies are needed

to evaluate the sustainable impact of this technology in classroom management (Jumriani et al., 2025).

Similarly, research conducted by Supriyanto, et al that Augmented Reality (AR) improves learning by integrating virtual objects into the real environment, providing contextual information. In vocational education, AR serves as an innovative medium, improving students' understanding and skills through hands-on experience. Applications include mobile AR for complex tasks, such as welding and sewing, which facilitates better learning outcomes. AR promotes engagement, motivation, and critical thinking, while also allowing students to visualize and manipulate 3D objects, leading to an immersive and effective learning experience. However, there is a lack of exploration regarding the long-term effects of augmented reality applications on vocational education outcomes, such as sustained student engagement, knowledge retention, and skills transfer to real-world scenarios (Supriyanto et al., 2023).

Research on the application "Augmented Reality for Equipment and Troubleshooting" Research conducted by Muhammad Afiq Jamil, et al showed a positive user experience, with 80% of students responding favorably, demonstrating the potential of AR in modern education. However this study did not address the long-term effects of AR on learning retention and academic performance. Future research could focus on longitudinal studies to assess how the continued use of AR technology affects educational outcomes over time (Jamil et al., 2023).

As for other research incorporating AR and VR technologies in classroom learning that to increase the accessibility of AR and VR technologies in educational settings, ensuring that all students, regardless of their background or resources, can benefit from these immersive learning experiences. In educational settings, AR personalizes the learning experience and significantly increases student engagement and motivation. However, an exploration of the long-term educational impact of AR and VR on student learning outcomes, which could provide insight into the sustainability and effectiveness of these technologies in improving academic performance over time has not been addressed in this study (Vashisht, 2024).

Finally, research related to Augmented Reality (AR) applications in learning, particularly in computer networking courses, improves students' understanding of abstract concepts and object models through dynamic visualization and interactive simulation. The research showed that the AR learning media was effective, with a material validity score of 0.85 and a design validity score of 0.86. In addition, the application received an 87% practicability rating from lecturers and students, highlighting its ease of use, motivational impact, attractiveness, and overall usefulness in education. However, this study did not address potential limitations or challenges in its implementation in diverse educational environments, nor did it explore the long-term impact of AR learning media on students' academic performance and knowledge retention in computer networking courses (Adi et al., 2024).

Based on the previous studies above, researchers consider it important to be able to comprehensively discuss the use of AR. The implementation of AR in education is in line with the TPACK (Technological Pedagogical Content Knowledge) framework which emphasizes the integration of technology in learning. However, its utilization is still limited due to obstacles including limited infrastructure and teacher competence. Therefore, this research aims to explore more deeply the utilization of AR in increasing student participation and engagement in learning while identifying effective implementation strategies according to the needs of students in the digital era so that it becomes a foundation for stakeholders, such as teachers, students, and education policy makers.

METHOD

To understand the role of interactive learning media in improving student engagement, this research was conducted using a qualitative approach using the literature study method. Sources such as scientific journals, books and relevant articles were analyzed to explore the benefits and challenges of using interactive media in education. The analysis process was conducted through several stages, such as:

1. Information Gathering: Data was collected from various relevant literature, including the results of previous studies highlighting the effectiveness of interactive learning media.
2. Data Grouping: The information obtained was classified based on specific themes, such as the advantages of interactive media, its effect on student participation, as well as the obstacles in its implementation.
3. In-depth Analysis: Each piece of information was examined to reveal patterns, trends and links between the use of interactive media and student engagement in learning.
4. Presentation of Findings: The results of the analysis are then systematically organized to provide a complete and comprehensive picture of this topic.

RESULT AND DISCUSSION

Concept of Augmented Reality (AR)

Augmented Reality (AR) or in Indonesian called augmented reality is a technology that allows direct and real-time display of a two- or three-dimensional virtual object into a three-dimensional real environment.

Augmented Reality is a combination of real-world elements and digital objects in one physical space. This technology is interactive and works in real-time, where virtual objects appear and visually merge with the real world in a three-dimensional format. The integration is possible thanks to supporting display devices, interactive input systems, and accurate tracking technology to ensure the integration between digital objects and the real environment (Artika, 2022). Augmented reality (AR) technology has changed the way students learn by bringing digital objects into the real world directly and interactively. This technology allows users to interact with three-dimensional virtual elements that appear around them, making the learning process more lively and interesting.

One of the figures who played a major role in introducing the concept of AR is Stephen Cawood and Mark Fiala. They explain that AR works by bringing together the real and digital worlds through visualizations that appear natural to the user. This technology is considered to improve the learning experience because it allows students to “see and interact” with concepts that were previously only imagined through textbooks. Augmented reality is a natural method that allows users to explore objects and data in three-dimensional form. AR is the result of integration between virtual reality and the real world, so that digital objects both two-dimensional (2D) and three-dimensional (3D) appear as if present and integrated with the physical environment directly (Cawood, S., & Fiala, 2008). Through this technology, users can still see the real world around them, but with the addition of virtual elements generated by the computer (Asharudin, F., & Utami, 2014).

Meanwhile, in the context of today's education, Anshul Dhaas through his study suggests that the application of AR has a positive impact on student learning outcomes. He highlighted how AR can help in various subjects such as natural science and history through concrete simulation displays, making it easier for students to understand concepts and increasing their interest in learning. In addition, AR is also able to create a fun learning experience and adapt to the learning styles of today's students (Dhaas, 2024).

Another figure, Bacca and his team, stated that AR can increase student motivation, strengthen social interaction in the classroom, and accelerate concept understanding. In their literature review, they also emphasized the importance of teacher training and infrastructure readiness as the main support for the successful use of AR in education. In addition to the benefits, they also noted challenges such as the lack of

supporting devices and the need for integration of AR content with existing curriculum (Bacca et al., 2014).

The utilization of Augmented Reality (AR) technology in education allows the integration of educational and entertainment elements, thus creating innovative learning methods both in formal environments such as schools and in non-formal environments. AR has characteristics and functions that are in line with learning media, namely as a means of conveying information between educators and students, clarifying the material presented, and increasing student motivation and interest in learning.

There is much hope for augmented reality in the educational environment. Through virtual features that overlap with the real world, augmented reality (AR) can be used to present interesting and engaging educational content in interactive learning. This allows students to learn through an intense and hands-on visual experience (Nistrina, 2021).

From this explanation, it can be concluded that AR as a learning media is a structured learning process that involves interaction between students, teachers, and teaching materials by utilizing AR technology in a supportive learning environment, so that learning objectives can be achieved optimally.

Implementation of Augmented Reality (AR) in Education

The implementation of technology in education, including Augmented Reality (AR), is part of a systemic effort to solve educational problems and improve the quality of learning through an integrated and innovative approach (Muhammad Aufa Muis, 2024). AR as a form of educational technology, offers a new way of designing, developing, utilizing, and evaluating the teaching-learning process to be more effective and relevant to the needs of the times.

The application of Augmented Reality (AR) in the education sector has brought significant transformation in the way students learn and teachers teach. AR allows learning to be more interactive, visual, and contextualized by presenting 3D virtual objects, simulated experiments, as well as more immersive learning experiences directly from students' devices (Rahmanto, 2024). There is much hope for augmented reality in educational environments. Through virtual features that overlap with the real world, augmented reality (AR) can be used to present interesting and engaging educational content in interactive learning. This allows students to learn through an intense and hands-on visual experience (Indahsari & Sumirat, 2023).

The benefit of AR is that it increases student motivation and engagement. Interactive visualizations help students understand abstract concepts that are difficult to explain with just text or images. For example, in science lessons, students can see a simulation of the water cycle or molecular structure directly, making learning more real and easy to understand. Empirical studies also show a significant increase in learning motivation after the implementation of AR in the classroom, especially in digital native students who are familiar with technology (Dhimas Mahendraa, 2024).

In addition, AR supports project-based learning and collaboration between students, and provides space for creative exploration. In the context of inclusive education, AR can be adapted to meet the needs of students with special needs, with more accessible and personalized learning media (Mulyahati et al., 2025).

There are many benefits of using Augmented Reality technology in interactive education. Some of these benefits include increasing student motivation and engagement, facilitating flexible learning, increasing conceptual understanding, and improving learning outcomes. However, there are also some issues to overcome, such as implementation costs, required infrastructure, and learning curves for teachers and students (Indahsari & Sumirat, 2023). However, the main challenge in AR implementation is the disruption of access to technology and infrastructure, especially in regions with lower daylight resources. For many educational institutions, the most important factors are the relatively low cost of AR and a reliable internet connection (Rahmanto, 2024).

From the above discussion, it can be understood that AR offers great opportunities to improve the quality of learning in schools, both in terms of motivation, concept understanding, and inclusiveness. For optimal implementation, it needs support from various parties, ranging from technology providers, the government, to teacher training and content development that is integrated with the national education curriculum.

The Appropriateness of Augmented Reality (AR) to the Needs of Students in the Digital Era

Augmented Reality (AR) technology is in line with the needs of students in the digital era because it can encourage enthusiasm for learning, increase participation, hone digital literacy skills, and improve academic achievement. AR presents an interactive and comprehensive learning process, in accordance with the characteristics of how today's digital generation learns.

Augmented reality (AR) is increasingly recognized as a viable approach to address the needs of learners in the digital era. The following is an overview of the relevance of AR in supporting today's learning, based on various recent research results:

1. Increasing student motivation and needs.
   The use of AR creates a more lively and interactive learning atmosphere, thus encouraging students to be more enthusiastic and active in learning activities (Lopez et al., 2025). AR significantly increases students' academic motivation and interaction, which has a positive impact on academic performance and sustainability of education (Schmid et al., 2024).
2. Improving Academic Achievement
   Various studies have shown that the application of AR in the learning process has a positive impact on students' understanding and their academic achievement. The majority of students show a favorable response to the use of AR, characterized by increased satisfaction and learning drive. Students who learn with AR show significant improvements in knowledge and retention of material, both in regular and special needs students (Arias et al., 2020)
3. Adapting to Various Learning Styles
   AR is able to adjust to various learning preferences, be it visual, auditory, or kinesthetic, so that it can accommodate the needs of each individual. For students who are less suited to traditional ways of learning, an interactive and visual approach through AR is an alternative that is easier to understand (Redha, 2025).
4. Accelerate and Simplify Material Understanding
   With the help of AR, students can learn material more efficiently and effectively because they not only read or listen to explanations, but can also directly interact with the content presented.
   This technology allows the creation of contextualized learning, such as experiencing simulations of historical events or scientific experiments, without being limited by space and time (News Unram in Pendidikan Teknologi, 2024).
5. Efficiency in Access and Use
   AR can be used through devices that are already commonly owned by students such as smartphones or tablets, making it easily accessible. In addition, AR also offers efficiency in terms of cost and time, for example by replacing the need for real laboratory or field study activities through virtual simulations (Yeremia et al., 2025).
6. Supports Collaborative Learning
   AR facilitates collaboration and social interaction, which are essential for the development of 21st century skills such as communication and teamwork (Upadhyay et al., 2024).

The use of Augmented Reality (AR) in education faces various challenges, especially in terms of its suitability to the needs of students. One of the main obstacles is the limited infrastructure and technological devices. Not all schools have adequate facilities, such as stable internet connections or sophisticated devices such as tablets and smartphones. The price of these devices is also still relatively expensive for most educational institutions (Anggita, 2025). In addition, the availability of AR content relevant to the curriculum is still very limited. The process of developing appropriate materials requires time, money, and cooperation between technology developers and education experts. Meanwhile, teacher readiness is also an

important concern. Many educators are not familiar with AR technology, so special training is needed so that they are able to utilize it optimally in the teaching and learning process (Anggita, 2025) (Kuswinardi et al., 2023b).

On the other hand, the use of AR also faces technical obstacles such as system glitches, device malfunction, or app incompatibility. Data security risks also arise if devices are not equipped with adequate protection. Another challenge is the significant digital divide, especially for students from remote areas or underprivileged families who do not have access to devices and the internet. This gap can widen the gap between students who are well-off and those who are not. In addition, excessive use of AR can also have negative health impacts, such as eyestrain, headaches, and decreased social interaction due to excessive focus on the virtual world. Finally, dependence on technology can reduce students' interest in using conventional learning methods, such as reading books or solving problems manually. All of these challenges need to be considered in designing an effective AR integration strategy in education.

Integration of Augmented Reality (AR) with Active Learning Models

Integration of Augmented Reality (AR) with active learning models can significantly improve student interactivity, engagement, and understanding. AR allows students to interact directly with virtual objects in a real-world context, for example touching, hearing sounds, and seeing 3D visualizations, which can improve memory and concept understanding (Mandasari et al., 2024).

The use of Augmented Reality (AR) in active learning makes the learning process more relevant to real situations, more fun, and involves students directly. Not only deepening the understanding of the material, AR also helps students hone their critical thinking, communication, and collaboration skills, which are important skills needed in today's modern era (Selamat, A., & Kamaruddin, 2019).

Active learning models such as Discovery-Based Learning, Game Based Learning, and Skill Training can be combined with AR to increase student engagement in the learning process (Pretiza et al., 2024). AR can also be used in project-based learning, where students work together to create AR content that explains certain concepts, thus encouraging collaboration and active participation.

In addition, experiments and simulations play an important role in building practical understanding of scientific concepts. AR can overcome physical limitations in laboratory experiments, such as expensive materials or hazards associated with certain experiments. For example, AR allows students to view complex chemical reactions or biological processes through three-dimensional visualizations that students can interact with directly. This not only enhances students' understanding, but also motivates them to explore concepts in greater depth (Melliofatria, 2024).

In group discussions and collaboration, students can use AR to display and modify data or three-dimensional objects relevant to their learning topics. Thus, AR facilitates more effective communication between students and allows them to share insights in a more engaging and collaborative way (Bacca et al., 2014).

The use of AR in interactive learning allows students to learn in a real and direct way, stimulating critical thinking and increasing interest in learning (Ilmawan Mustaqim, 2016). The integration of Augmented Reality (AR) with active learning models has a significant impact on the quality of education. AR enriches the learning experience by providing real-world visualizations, simulations and interactions that enhance student engagement in learning. Through a more immersive and context-based approach, AR not only helps students understand abstract concepts, but also motivates them to think critically and creatively in solving problems. Looking ahead, AR has great potential to continue changing the way we educate the next generation, providing a more interactive, engaging and immersive learning experience.

The application of Augmented Reality (AR) technology in education brings a breath of fresh air in the way students learn and interact with subject matter. AR is able to create an interactive and immersive learning experience, where students are not only passive recipients of information, but are directly involved in the learning process. Through simulation, visualization,

and three-dimensional interaction, students can more easily understand material that was previously considered abstract or difficult, such as cell structure, solar system, or concepts in physics (Kuswinardi et al., 2023).

One of the main impacts of implementing AR is increased student engagement. When material is presented in a more lively and fun way, students tend to become more active, interested, and focused in following the lesson. This is a far cry from traditional approaches that tend to be monotonous. AR makes learning a fun and intellectually challenging activity (Kaharuddin et al., 2025).

Furthermore, AR also plays a role in improving students' understanding of complex concepts. With AR's visualization capabilities, concepts that are difficult to visualize conventionally can be displayed in a virtual form that students can see and manipulate directly. This accelerates the understanding process and helps students retain information longer in their memory (Nabila Alfitriani, Wisheila Ayunisa Maula, 2021). Besides increasing engagement and understanding, AR technology also encourages collaboration between students. Many AR-based learning applications are designed to be used in groups, thus triggering teamwork, communication, and problem solving (Nabila Alfitriani, Wisheila Ayunisa Maula, 2021). This is a golden opportunity for students to develop social and communication skills that are important in real life.

Another advantage of this technology is its ability to provide personalized learning. Students with different learning styles can get a learning experience that suits their needs. For example, visual students can be helped more by AR graphic displays, while kinesthetic students can take advantage of its interactivity (Kuswinardi et al., 2023a). This makes learning more inclusive and adaptive.

Another positive impact is increased information retention and student learning satisfaction. When students feel emotionally and intellectually involved in the learning process, they tend to be more confident and satisfied with what they have learned (Sari et al., 2024; Rizqi, & Faujianor, 2024). This also contributes to their intrinsic motivation to continue learning and developing. Last but not least, AR also stimulates students' creativity and critical thinking skills. Through exploration and simulation, students are encouraged to think innovatively and find solutions to various problems faced in the learning context (Sari et al., 2024). Thus, AR not only transforms the way students learn, but also the way they think and act.

However, the application of AR in learning is not free from challenges. Among them are limited access to technological devices and lack of training for teachers. Not all schools have adequate facilities or human resources ready to adopt this technology. Therefore, an inclusive implementation strategy and continuous training support are needed so that the potential of AR can be fully utilized in education.

Although Augmented Reality (AR) technology has great potential to improve the learning process, its application in education still faces various obstacles. One of the main obstacles is the limited supporting facilities and infrastructure, especially in schools that do not have adequate technology facilities (Fitriani, Somariah, 2024). In addition, the ability of teachers to use and apply AR in the teaching and learning process is still a challenge, because not all teachers have the required knowledge and technical skills (Dian Juli Lestari, M. Jaya Adi Putra, 2025).

To overcome these challenges, further research is needed. One of them is the development of AR materials that are in accordance with the national curriculum and are easily accessible to teachers and students (Alzahrani, 2020). In addition, long-term research is needed to evaluate the extent to which AR affects learning achievement, enthusiasm for learning, and students' critical thinking skills over a long period of time (Chang et al., 2022). It is also important to involve various levels of education, including students with special needs, so that the application of AR is more equitable and inclusive (Jannah et al., 2024). No less important, evaluating the effectiveness of teacher training and analyzing the cost efficiency and benefits of using AR can be an important basis for formulating technology-based education policies in the future (Hartanti & Kurniawan, 2022).

CONCLUSION

The application of Augmented Reality (AR) technology in education has provided a new color in the teaching and learning process. AR makes learning activities more interesting by displaying three-dimensional virtual objects and simulations that can be accessed directly by students through digital devices. This has been proven to increase learning enthusiasm, help students understand difficult material, and encourage active engagement in the classroom. Even for students with special needs, AR can be a more friendly and accessible learning media. However, there are barriers that need to be overcome, such as limited devices, internet connection, and the need for training for teachers to be able to integrate this technology effectively.

In addition, AR is very compatible with the learning styles of today's students who are accustomed to digital technology. AR is able to follow the needs of students who learn visually, auditory, and kinesthetically, and supports activity-based learning and collaboration. When AR is combined with active learning methods, such as collaborative projects or simulated experiments, students are not only the recipients of the material, but also directly involved in the real learning process. Thus, AR not only improves students' understanding of the material, but also hones critical thinking, creativity, and teamwork skills. In the future, AR has great potential as a learning tool that can answer the challenges of education in the digital era in a comprehensive and fun way.

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