

Revolutionizing Learning Engagement: Augmented Reality Smart Cards for Active Student Participation

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Abstract

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This study explores the implementation of Augmented Reality (AR) Smart Cards in secondary schools in Mataram, Indonesia, focusing on their impact on student engagement and the challenges faced by teachers and students in adopting this technology. AR Smart Cards enhance interactive learning by overlaying digital information on real-world objects, creating a more immersive educational experience. Specific examples of improvement include an increase in student participation during interactive activities, such as physics simulations where students actively engage with 3D visualizations of complex phenomena, and enhanced problem-solving in geography, where students analyze and interact with 3D maps of regions. A qualitative approach with a phenomenological research design was employed, involving in-depth interviews with teachers and students, along with classroom observations. The findings reveal that AR Smart Cards significantly improve student engagement, motivation, and understanding of complex concepts. However, challenges such as limited access to devices, infrastructure constraints, and insufficient teacher training were identified as barriers to effective implementation. The study recommends investing in technology infrastructure, providing comprehensive teacher training, and fostering a collaborative learning environment to ensure the successful integration of AR in classrooms. This research contributes valuable insights into the potential of AR-based learning tools in enhancing student participation and educational outcomes. Future research could explore the long-term effects of AR on learning retention, investigate the impact of AR in diverse educational settings, and examine the effectiveness of AR tools across various disciplines to identify optimal integration strategies.

INTRODUCTION

Augmented Reality (AR) has emerged as a transformative technology in education, enhancing traditional learning by overlaying digital information onto the real world, thereby creating immersive and interactive experiences (Arici et al., 2021). In the context of education, one innovative implementation of AR is AR Smart Cards-smart equipped with AR technology to provide a more interactive and immersive learning experience. AR Smart Cards allow students to directly interact with virtual objects that appear when the cards are scanned using mobile devices, such as smartphones or tablets. This allows learning materials, which were previously conveyed in the form of text or two-dimensional images, to become more visual and engaging for students. This integration facilitates a deeper understanding of complex subjects, making learning more engaging and effective (Lampropoulos et al., 2022).

Despite its potential, the successful implementation of AR in educational settings is influenced by the perceptions and readiness of both educators and students (Dendodi et al., 2024). Teachers' acceptance and integration of AR technologies are crucial, as their attitudes toward these tools significantly affect their adoption and effectiveness in classrooms (Ibáñez & Delgado-Kloos, 2018). Similarly, students' positive perceptions of AR can enhance their motivation and engagement, leading to improved learning outcomes (Akçayır & Akçayır, 2017).

In Indonesia, integrating AR into education presents unique challenges. Issues such as limited technological infrastructure, varying levels of digital literacy among educators, and institutional readiness can hinder the effective adoption of AR tools (Kemendikbud, 2023). Addressing these challenges requires targeted strategies, including professional development for teachers and investments in necessary infrastructure.

Research indicates that AR can significantly enhance student engagement and motivation. For instance, Akçayır & Akçayır, (2017) found that AR applications in educational settings increased students' interest and participation. However, the effectiveness of AR is contingent upon thoughtful instructional design and the preparedness of both educators and students to integrate these technologies into the learning process (Garzón et al., 2019).

Previous studies have extensively reviewed how AR can increase student motivation and engagement. However, the main challenge in implementing AR lies in the perceptions of both teachers and students toward this technology. Teachers' perceptions regarding the ease of use, pedagogical value, and practicality of AR influence the extent to which they integrate AR into their teaching (Ibáñez & Delgado-Kloos, 2018). Similarly, students' perceptions of AR can either strengthen or hinder their engagement with learning material. Therefore, it is crucial to understand how both groups interact with AR to optimize its application in education (Rahmat et al., 2023).

Understanding the perceptions of teachers and students toward AR is essential for optimizing its application in education. By identifying key factors that influence acceptance and engagement, this research aims to provide insights into the practical challenges of AR implementation and how educators can navigate these obstacles to foster a more dynamic learning environment. Exploring these perspectives will contribute to the development of strategies that enhance the effectiveness of AR-based learning (Nuraeni et al., 2024)(Trikotama et al., 2024), ensuring that both teachers and students can fully leverage its potential.

To date, research on AR in education has primarily focused on its technical capabilities and overall impact on learning outcomes (Einsthendi et al., 2024), with limited exploration of how teachers and students perceive and interact with this technology. For instance, prior studies have examined the cognitive benefits of AR but have not extensively investigated the challenges educators face in integrating AR tools into traditional curricula (Garzón et al., 2019). Additionally, existing literature lacks in-depth analysis of students' attitudes toward AR-enhanced learning experiences, particularly in different learning contexts and disciplines (Rahmat et al., 2023).

However, despite the proven benefits of AR in enhancing student engagement, its implementation still faces barriers such as limited infrastructure, insufficient teacher training, and unequal access to devices (Kemendikbud, 2023). Therefore, this study aims to explore the perceptions of teachers and students regarding the use of AR Smart Cards in enhancing active student engagement, as well as the challenges they face in implementing this technology in the classroom. By understanding the factors influencing adoption and engagement, this research aims to provide insights that can be used to optimize the application of AR in classrooms.

Therefore, this study aims to analyze the perceptions of teachers and students regarding the use of AR in fostering active learning engagement. Additionally, it seeks to identify the challenges encountered during the implementation of this technology in educational settings. By understanding these aspects, this research aspires to provide recommendations for optimizing AR-based learning, ensuring that it serves as an effective tool for enhancing student participation and educational experiences.

This research is significant as it provides valuable insights for educators, policymakers, and technology developers in refining AR learning strategies. By examining how teachers and students perceive and interact with AR, the findings of this study are expected to contribute to the broader discourse on educational technology adoption, ultimately leading to more effective and inclusive digital learning environments.

METHODS

This study employs a qualitative approach with a phenomenological research design (Creswell, 2020), to explore the implementation of Augmented Reality (AR) Smart Cards in high schools in Mataram. A phenomenological approach was chosen to capture the lived experiences of teachers and students in their interactions with AR Smart Cards during the learning process. The study was conducted at several Senior High Schools (SMA) in Mataram, Indonesia, selected for their prior exposure to or involvement in the use of AR in education. The selection of schools allows for a focused exploration of AR implementation in secondary education settings, providing insights into how this technology affects learning engagement and outcomes.

A purposive sampling technique (Merriam & Grenier, 2019), it was employed to ensure that participants had substantial experience with AR in educational settings. The sample consisted of 20 teachers who had incorporated AR Smart Cards into their teaching practices and 60 students who had interacted with AR Smart Cards as part of their learning activities. The study was conducted over a period of six months, from January to June 2023, during which the researchers observed the implementation of AR Smart Cards in classrooms. The inclusion criteria required teachers to have a minimum of two years of teaching experience, with a specific focus on digital learning tools, and students were selected if they had participated in AR-based lessons. This purposeful selection ensures a comprehensive understanding of the adoption and experiences with AR in different educational contexts. To make it clearer how the steps in the research are, it can be seen in the following Figure 1.

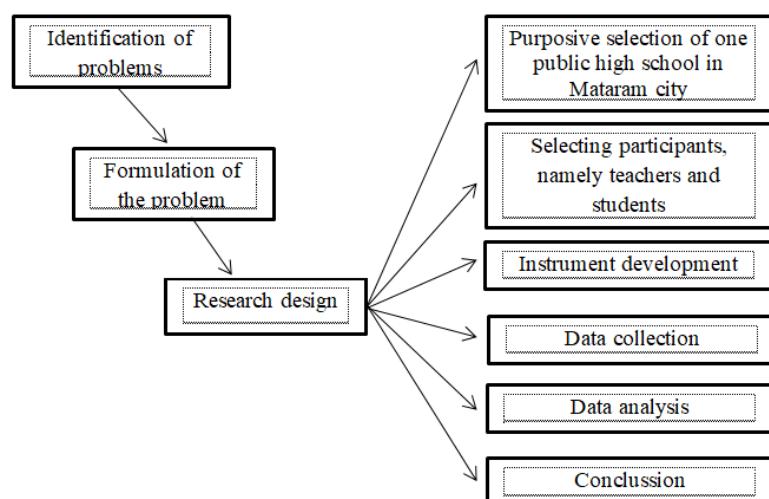


Figure 1. Research Steps

Data collection was conducted through in-depth, semi-structured interviews and participant observations. The interview questions were developed based on a review of existing literature on AR in education and technology acceptance models. The interview guide was pilot-tested with a small group of teachers and students to ensure clarity, relevance, and reliability. Each interview lasted between 20 to 30 minutes and was conducted in a flexible manner, allowing participants to express their experiences freely while maintaining focus on key research questions. The interviews were recorded, transcribed, and analyzed to uncover themes related to AR Smart Cards' use, engagement, and learning outcomes.

Additionally, participant observations were conducted in classrooms where AR Smart Cards were being used, providing a direct insight into how students and teachers interacted with the technology. Observations allowed the researcher to gather data on the contextual factors that influenced AR implementation and student engagement. The collected data were transcribed and coded manually to identify emerging patterns and themes.

The data were analyzed using thematic analysis, following the model by Miles et al., (2014), the analysis consisted of three main stages: data reduction, data display, and conclusion drawing. The first stage, data reduction, involved reviewing transcriptions and field notes to identify key themes related to AR Smart Cards' effectiveness, usability, and engagement. The second stage, data display, organized the themes into matrices and diagrams to illustrate relationships between concepts, such as how different levels of AR interaction influenced student participation and learning outcomes. Finally, the third stage, conclusion drawing, involved verifying the themes by cross-referencing them with existing literature and expert feedback to ensure reliability and validity. By systematically applying thematic analysis, this study provides a structured and rigorous interpretation of the data, offering valuable insights into the practical challenges and benefits of AR Smart Cards in education (Majumdar, 2022).

RESULTS AND DISCUSSION

Result

The use of Augmented Reality (AR) Smart Cards in education has shown significant potential in enhancing student engagement, motivation, and understanding of complex concepts. Based on the interviews and classroom observations, several key findings emerged.

Increased Student Engagement

Many students reported a significant increase in their engagement with the learning material. One student shared:

"Before using AR, I just read the textbook. But with AR Smart Cards, I can actually see the 3D models of the things we study, like the Earth's layers. I feel more involved in the lessons."

Another student stated:

"The AR Smart Cards made me more excited to learn. I didn't just read a chapter; I could interact with it and see things from different angles, which really helped me understand the subject better."

This direct engagement with the content, particularly in subjects like science and geography, was frequently mentioned by students as a key factor that enhanced their learning experience. Observations showed that students spent more time interacting with the AR features and were more likely to engage in class discussions.

Improved Understanding of Abstract Concepts

The use of AR Smart Cards also facilitated a deeper understanding of abstract concepts, especially in subjects such as physics. A teacher explained:

"In physics, concepts like force and motion are hard for students to visualize. With AR Smart Cards, they can interact with 3D models of these concepts and see how they work in real time. This makes it much easier for them to grasp complex ideas."

Several students echoed this sentiment, highlighting how they could now visualize abstract phenomena such as particle motion and gravitational force, which were previously difficult to comprehend through traditional methods.

Challenges in Technology Access and Teacher Preparedness

However, challenges related to technology access and teacher preparedness were also noted. One teacher shared:

"The AR Smart Cards are a fantastic tool, but not all of my students have access to smartphones or tablets that can support the AR apps. It's a bit frustrating when some students can't participate fully in the lessons."

Additionally, teachers expressed concerns over the lack of adequate training. A teacher commented:

"While the AR Smart Cards are effective, I don't feel fully prepared to use them to their maximum potential. We need more training on how to integrate them into the curriculum." These challenges were consistent across several schools and were particularly evident in schools with fewer resources.

Discussion

Effectiveness of Augmented Reality Smart Cards on Student Engagement

The use of Augmented Reality (AR) Smart Cards in education has great potential to enhance student engagement with the learning material and increase their interaction during the learning process. According to the research conducted by Álvarez-Marín & Velazquez-Iturbide, (2022), AR technology in education allows students to interact directly with virtual objects that emerge from physical media, in this case, smart cards, transforming the way they engage with learning content. This creates a more immersive and interactive experience compared to conventional learning methods, which tend to be passive. The effectiveness of AR in increasing student engagement has been demonstrated in several studies showing that students who use AR in learning are more motivated, more engaged, and more active in the classroom (Acesta & Nurmaylany, 2018). AR allows students to see, feel, and interact with the learning material directly, enhancing their understanding of concepts that are difficult to grasp when conveyed through text or two-dimensional images.

In a study by Akçayır & Akçayır, (2017), it was found that AR significantly enhances student engagement in ways that traditional media cannot. AR offers students the opportunity to access more varied and visual content, providing a deeper learning experience. Students using AR Smart Cards in class reported feeling more connected to the material and more motivated to complete the tasks assigned. This relates to the theory of active engagement, where students are not only passive recipients of information but also actively engage in the learning process through exploration and direct interaction (Rosidin et al., 2024).

One of the greatest benefits reported by teachers is the increased emotional engagement of students. The more enjoyable and engaging experience provided by AR serves as an emotional stimulus that increases students' interest and motivation. In a study by Acesta & Nurmaylany, (2018), it was found that AR technology enhances the emotional engagement of students in learning, which in turn improves the effectiveness of learning itself. When students feel emotionally connected to the learning material, they are more likely to remember and apply the information they have learned. AR Smart Cards provide a more engaging and interactive experience, which potentially reduces the boredom often experienced by students during conventional learning.

One of the most interesting results from this study is the influence of using AR Smart Cards on improving the understanding of abstract concepts that are difficult to grasp through conventional learning methods. For example, in physics learning, AR allows students to see three-dimensional simulations of physical phenomena, such as forces or particle motion. These visualizations provide students the opportunity to manipulate the objects they see, giving them greater control over their learning. As explained by Bacca et al., (2014), AR allows students not only to see these concepts but also to experience them in a more tangible form. This helps students better understand these concepts in a more direct and intuitive way, improving their comprehension and reducing the difficulties they experience in understanding abstract theories.

Additionally, the use of AR Smart Cards increases interactivity in the classroom. In a study by Rosidin et al., (2024), it was found that students who used AR were more likely to participate in class discussions and more active in solving problems. Student engagement in AR-based classes increased because they could directly interact with the objects displayed through AR cards. This gave them the opportunity to better understand the relationships between concepts and how they could be applied in real life. This activity fosters collaboration among students, enhances classroom dynamics, and strengthens mutual trust among them. This aligns with social learning theory, which states that social interaction and collaboration enhance the quality of understanding and student engagement.

The research by Cakir & Korkmaz, (2019) also shows that AR plays a significant role in enhancing the practical learning experience, where students can apply what they have learned in more relevant and real-world contexts. For example, students learning about geography or biology using AR Smart Cards can see maps or three-dimensional models of organisms, which helps them better understand the concepts being studied. Such learning leads to more effective knowledge application and allows students to retain information in the long term. By facilitating a more enjoyable and interactive learning experience, AR not only enhances students' cognitive engagement but also increases their affective and social engagement.

One factor that needs to be considered is students' acceptance of technology. According to the research by Fu et al., (2022), students are more likely to accept and quickly adapt to new technologies, especially those that are relevant to their everyday lives. With AR Smart Cards, which use devices like tablets or smartphones that are already familiar to many students, this technology feels less foreign and is easily accessible. The AR-based learning experience also gives students a greater sense of control over how they learn, making them feel more engaged and motivated (Einsthendi et al., 2024).

The results of this study confirm that the use of AR Smart Cards significantly enhances students' motivation, participation, and understanding. By creating a more immersive learning experience, AR reduces boredom and provides students with opportunities to engage more with the learning material. This experience leads to deeper learning and better skill reinforcement. Given these results, it is crucial for educators and policymakers to further explore the potential of AR in education and develop policies that support the wider application of this technology.

Challenges in the Implementation of Augmented Reality Smart Cards

The implementation of Augmented Reality (AR) Smart Cards in education opens up numerous new opportunities. However, behind its great potential, there are several challenges that must be addressed to maximize the effectiveness of this technology. These challenges not only cover technical aspects but also pedagogical and psychological factors, all of which play a crucial role in the successful implementation of AR in the classroom. Although AR Smart Cards have been proven effective in enhancing student engagement and motivation (Einsthendi et al., 2024), these barriers often become limiting factors in their adoption by many educational institutions. As found in the study by Khalida, (2021), technical constraints often represent one of the main challenges in implementing AR technology on a broad scale in the education system.

One of the biggest challenges faced by many schools is the limited access to devices required to support the use of AR Smart Cards. Devices such as tablets or smartphones that are compatible with AR applications may not be available in all schools (Amalia & Munif, 2023), especially in resource-limited areas. In many developing countries, this infrastructure issue significantly hampers the potential for AR adoption, which requires more powerful hardware and sometimes specialized software to effectively run AR applications. Research by Fu et al., (2022) highlights how the digital divide in many schools, both in developed and developing countries, can be a significant barrier to the implementation of AR technology. In schools with limited resources, adequate devices to run AR are still scarce, leading to inequality in technology accessibility in the classroom.

In addition to the technical issues related to devices, infrastructure limitations also pose another major challenge (Lutfiah, 2024). AR technology requires a stable and fast internet connection to download and access the interactive content available in AR applications. In many schools, particularly in rural areas, unstable or unavailable internet networks can prevent students and teachers from using AR Smart Cards effectively. This is consistent with findings by Hidayat & Kusdibyo, (2022), who note that adequate technological infrastructure is essential for the successful implementation of new technologies in education. Without access to fast and reliable internet connections, the use of AR in classrooms becomes limited and ineffective.

The issue of teacher training limitations also presents a significant barrier to the adoption of AR Smart Cards. New technology always requires time and effort to master, and teachers need

adequate training to effectively integrate AR into their teaching practices. Without proper training, teachers may feel unprepared or hesitant to use AR in their classrooms. According to research by Rosidin et al., (2024), teachers' inability to fully utilize technology can diminish the potential benefits that students can gain from using that technology. In some schools, particularly those in remote areas, teacher training on how to use AR is still limited, making AR implementation ineffective. The lack of understanding about how this technology can be integrated into existing curricula also becomes a major obstacle to its widespread adoption (Aditia, 2024).

In addition to technical and training challenges (Khalida, 2021), there are also psychological barriers that need to be addressed, both from the perspective of teachers and students. Some teachers may feel anxious or skeptical about using new technology in the classroom, especially if they perceive it as overly complex or difficult to understand. Resistance to new technology often stems from the fear of not being able to operate new devices or applications. In the research by Bacca et al., (2014), it was found that some teachers were reluctant to adopt AR technology because they were concerned about difficulties in operating the technology or adapting their teaching methods. This study also notes that a lack of confidence in using new technology can hinder its effective implementation in teaching.

Furthermore, students may also face psychological barriers to accepting new technology. Some students may feel anxious or uncomfortable with the changes brought about by the use of AR in the classroom (Alifa et al., 2024). They may be more accustomed to traditional learning methods and feel that the new technology may disrupt their way of learning or make them feel incompetent in using the devices. The acceptance of this technology by students largely depends on how much they can see the immediate benefits of using AR in supporting their learning. As found in the study by Acesta & Nurmaylany, (2018), students who are not familiar with AR or those who have limited access to technology may feel intimidated by this new experience. Therefore, it is important to introduce the technology gradually and provide psychological support to help students feel more comfortable and confident.

From a psychological perspective, there is also the challenge of dependency on technology. The use of technology in education must be handled carefully, as there is a risk that students may focus more on the technology than on the material being taught. As noted by Fu et al., (2022), while AR can enhance student engagement, there is also the potential that this technology may distract students if not used wisely. This indicates that while technologies like AR Smart Cards have great potential, their use must be accompanied by proper oversight to ensure that learning objectives are still achieved.

In addition to technical and psychological challenges, there are also pedagogical challenges that need to be addressed in the implementation of AR Smart Cards. Teachers need to understand how this technology can be integrated into the existing curriculum and how best to use it to enhance student learning. In many cases, traditional teaching methods, which are more lecture-based or instruction-driven, are not always suitable for use with AR, which is more interactive and exploratory. As found by Dendodi et al., (2024), teachers need to design teaching methods that allow students to explore and interact with the material in greater depth, which requires a shift in their pedagogical approach.

Finally, while AR Smart Cards offer great potential to enhance learning, cost challenges are also an important factor. Acquiring adequate hardware and developing AR software that is compatible with the curriculum can be quite costly. Some schools may not have sufficient budgets to fund the technological investments required for the widespread implementation of AR. In research by Zhang et al., (2022), this was identified as one of the main barriers that could slow down the adoption of AR technology in education, particularly in schools with limited budgets.

CONCLUSION

This study highlights the effectiveness of Augmented Reality (AR) Smart Cards in enhancing student engagement, motivation, and understanding of complex concepts. The use of AR Smart Cards enables active participation, particularly in subjects like physics, where students can visualize and interact with abstract concepts. To fully maximize the benefits of AR, educators should focus on providing ongoing professional development, ensuring access to necessary technology, and fostering collaborative learning environments. Policymakers must also invest in infrastructure to support AR implementation across schools. These actions can help overcome current barriers and increase the effectiveness of AR-based learning.

While the findings are promising, the study has limitations, such as a small sample size and a focus on schools in Mataram, Indonesia. Future research should explore the long-term effects of AR on learning retention, evaluate its effectiveness across different subjects and educational levels, and examine its feasibility in resource-limited settings. By addressing these gaps, future studies can further refine AR implementation strategies and provide deeper insights into its potential for transforming educational practices.

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