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Opportunities and Challenges for Using Augmented Reality-Based Learning Media in Learning Chemistry in The Era Of Society 5.0

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ABSTRACT

This research aims to explore the use of augmented reality (AR) in the context of chemistry learning with a descriptive qualitative approach. Through in-depth analysis of a number of literature sources, including scientific articles, books, and related publications, this research identifies the opportunities and challenges associated with the integration of AR in chemistry learning. One of the main focuses is on the potential of AR in improving students' understanding of abstract chemistry concepts. The results of this literature study highlight the important role of AR in providing a more interactive learning experience, clarifying difficult-to-understand chemistry concepts, and the challenges in developing and integrating this technology into educational curricula. The implications of these findings can provide guidance for educational institutions to effectively adopt AR in chemistry learning.

Keywords: Augmented Reality, Learning Media, Chemistry

INTRODUCTION

Education is a series of complex processes that have various dimensions, which aim to support student development in all aspects of life (Pongpalilu et al., 2023). Education plays a significant role in maintaining human survival (Ramli et al., 2023). Education has a close relationship with Society 5.0, which is a concept of society that integrates advanced technology in various aspects of life. In the educational context, Society 5.0 presents a significant paradigm shift. The integration of advanced technology into learning is the main driver in increasing the effectiveness of the teaching and learning process. Apart from that, the Society 5.0 era involves the application of technology in various fields of science, including chemistry. Chemistry learning in the Society 5.0 era is no longer limited to conventional approaches that use textbooks and static presentations. Rather, the use of advanced technology, such as augmented reality, allows students to engage more directly with abstract chemistry concepts. Chemistry itself is a branch of natural science that reviews structure, transformation, characteristics, and principles, as well as theories and ideas that describe the process of changing substances (Hemayanti et al., 2020). In the context of learning, technology has changed the way we access, present, and interact with learning material (Ariani et al., 2023).

In the 21st-century education era, educators face great pressure to continue to explore creativity and innovation in their teaching strategies (Akbar et al., 2023). Through the

implementation of appropriate learning strategies, it will certainly have a big influence on student learning achievement (Akbar et al., 2019). This statement is closely related to the Society 5.0 era, where education is one of the fields that is significantly affected. The Society 5.0 era emphasizes the integration of advanced technologies such as artificial intelligence (AI), augmented reality (AR), and other technologies into everyday life, including education. In this context, the demand to explore creativity and innovation in teaching strategies reflects a response to the needs of a society that is increasingly connected to technology. Teachers can utilize technology to better explore the unique needs and potential of each student, so that they can provide appropriate and appropriate direction (Akbar & Djakariah, 2023). Thus, Society 5.0 brings an important shift in the learning paradigm, placing advanced technology as a primary tool to facilitate deeper understanding in the field of chemistry and prepare students to face the challenges of this increasingly connected era.

Learning media plays a crucial role in enriching the educational process, especially in chemistry learning in the modern era. According to research by (Smith et al., 2019), which conducted a meta-analysis of 102 studies on the effectiveness of learning media, it was found that learning media can increase conceptual understanding, improve critical thinking skills, and increase student learning motivation. This shows that learning media is not just a tool, but is also an important catalyst in improving the quality of learning, maintaining student interest, and deepening their understanding of complex chemical concepts. The evolution of learning media from traditional approaches to the digital era has changed the chemistry learning landscape significantly. Traditional approaches are often limited to textbooks, whiteboards, and live presentations from teachers. However, with the advent of technology, such as animation, simulation, interactive video, and augmented reality, students can now visualize and experience chemistry concepts more dynamically and realistically.

The use of innovative learning media can attract student interest. Detailed animations, realistic simulations, or augmented reality applications that allow direct interaction with chemical molecules can make learning more engaging and provide deeper understanding. According to (Sirakaya & Alsancak Sirakaya, 2018) who identified trends in studies conducted regarding AR, it shows that the number of AR studies in education has increased from year to year. (Vuta, 2020) one of the advantages of using augmented reality in education is that it can increase students' motivation to learn. Meanwhile, according to (Cai et al., 2022) who have conducted a meta-analysis of 23 studies on the impact of AR on student learning, it shows that AR has a significant positive effect on student learning outcomes. Other research shows that AR has a significant positive effect on science learning. AR can improve understanding of science concepts, improve problem-solving skills, and increase students' interest in learning (Alquraini et al., 2023). These results demonstrate that AR has a significant impact in educational contexts and provides a foundation for the use of this technology in developing innovative and effective learning experiences (Zhang et al., 2022).

This helps students to be more actively involved in the learning process, which in turn improves information retention and understanding of complex chemistry concepts. Its impact on chemistry learning is significant. For example, through animations or simulations, students can see how chemical reactions occur at the molecular level, which are difficult to understand with conventional approaches. Through augmented reality technology, students can "scan" molecules and study molecular structures interactively. All this not only enriches the learning experience but also helps students understand concepts that were previously difficult or abstract. This is because AR can be a powerful tool in helping someone to understand, train, and improve performance in matters that require understanding certain steps or procedures (Buchner et al., 2022). Therefore, the importance of learning media in the context of modern education, especially in chemistry learning, is undeniable. This evolution not only improves the quality of learning but also brings a more interesting, interactive, and engaging approach to understanding the complex world of chemistry.

Augmented Reality (AR) is a technology that combines real-world elements with virtual elements, creating experiences that enhance existing realities. According to (Pathania et al., 2023). Augmented reality is an interactive technology that changes the learning environment in the

classroom by providing a way to interact dynamically with the material and the teacher. This is done using devices such as smartphones, tablets, or special glasses that allow the insertion of virtual objects, images, or information into the physical environment. In the context of chemistry learning, AR is an interesting approach because it allows students to see and interact with abstract chemical concepts visually and practically. For example, by using an AR app on a mobile device, students can point the camera at specific molecules studied in chemistry class. They can then see the molecule appear in three dimensions on their device's screen, allowing them to rotate, zoom, or even manipulate the structure of the molecule. Another concrete example is the use of AR to visually show chemical reactions. Students can see how atoms interact and change into new molecules in their environment. They can see changes in shape, structure, and bonds between atoms directly, helping them understand the concept of chemical reactions more concretely and practically.

AR technology can also be used to create virtual laboratory simulations where students can conduct risk-free chemistry experiments, see how mixtures of substances interact, and understand the results of chemical reactions right before their eyes. Thus, AR provides a powerful tool in chemistry learning because it enables immersive, interactive, and direct visualization of chemical concepts that are generally difficult to understand using traditional media alone. This creates a more enjoyable learning experience and deepens students' understanding of the complex world of chemistry. These several things show that AR has great potential in enriching chemistry learning in the Society 5.0 era. AR integration opens up opportunities to provide a more interactive, visual, and fun learning experience in understanding complex chemistry concepts.

However, it is important to remember that the gap between technology and education needs to be addressed. Although AR offers very exciting possibilities, challenges such as the availability of adequate technological infrastructure, appropriate resources, training for educators, as well as accessibility for all students still need to be overcome. The bridge between technology and education is the key to achieving optimal learning goals. Collaboration between various parties, including schools, technology developers, government, and society, will be the foundation that enables the application of AR in chemistry learning. By addressing these challenges, we can create learning environments that inspire, motivate, and support students in understanding chemistry more deeply and enjoyably. AR is becoming an important tool in bringing chemistry education to a more innovative and effective level in this increasingly connected Society 5.0 era. Through this article, we will discuss the opportunities and challenges of using augmented reality-based learning media in chemistry learning in the era of society 5.0 in more depth.

METHODS

In principle, a research method is a scientific method used to collect information with specific objectives and special benefits (Kurniawan et al., 2023). This research applies a qualitative descriptive approach. Researchers also refer to several previous studies that are relevant to the research topic, namely augmented reality-based learning media. To collect data, this research uses literature study techniques, taking information from reading sources related to the opportunities and challenges of using augmented reality-based learning media in chemistry learning in the era of society 5.0.

RESULTS AND DISCUSSION

A. OPPORTUNITIES FOR USING AUGMENTED REALITY-BASED LEARNING MEDIA IN CHEMISTRY LEARNING

Opportunities for using augmented reality (AR)-based learning media in chemistry learning include several things, namely:

1. Increased Student Engagement

AR can make chemistry learning more interesting with real three-dimensional (3D) visualization of molecules and chemical reactions. This can increase students' interest and involvement in

understanding abstract chemical concepts so that it has an impact on improving student learning outcomes. This is supported by research conducted by (Garzón & Acevedo, 2019) that the use of AR technology has a significant impact on improving student learning. Apart from that, according to (Low et al., 2022), the application of AR technology has a positive impact on the learning motivation and performance of chemical engineering students. AR allows students to see molecules and chemical reactions in a more realistic and interactive form. AR has proven effective in helping students visualize abstract concepts, increasing their understanding of molecular structure, and making learning more engaging and interactive.

Students can view molecules from many angles and understand molecular structure and interactions in a way that is difficult to achieve through traditional learning methods. This is what makes learning more interesting and attracts students' attention. With AR, students can 'touch' and manipulate molecular structures virtually. This provides practical experience that is difficult to find in conventional learning. Students can build, assemble, or even see chemical reactions directly, thereby deepening their understanding of chemical concepts. Chemical concepts that are often considered abstract can be more easily understood through visualization in 3D. For example, reactions between various molecules or complex chemical structure concepts can be illustrated more clearly through AR, making it easier for students to understand and internalize these concepts. With the ability to interact directly with learning material, students become more active in the learning process. They can experiment with chemistry concepts without risk and learning becomes more fun, sparking their interest to explore further. Increased student involvement in chemistry learning thanks to AR can have a positive impact on their understanding of the lesson material. With stronger visualization and a more immersive learning experience, AR opens the door to more engaging and effective learning in chemistry.

2. Interactive Learning Experience

AR allows students to interact directly with chemistry learning materials, such as building and manipulating molecular structures virtually. This provides a more interactive and fun learning experience. According to (Redep & Hajdin, 2021), the integration of AR with game elements has great potential to improve the learning process, create a more interesting and innovative environment for students, and increase the overall effectiveness of teaching. AR allows students to become the main actors in the learning process. They can build, assemble, or manipulate molecular structures virtually. Through this direct interaction, students not only become observers but also active actors in exploring and understanding chemical concepts. With AR, students can conduct experiments and interact with chemical materials without the risk of accidents or failure. They can view chemical reactions, change parameters, and see the results directly without having to use actual chemicals. This allows for risk-free exploration, leaving room for limitless creativity.

Direct engagement with learning material through AR tends to increase student motivation. A fun and interactive learning experience triggers their interest to become more involved in the learning process. This can increase their curiosity about chemistry and strengthen their motivation to learn. AR also allows for personalized learning experiences. Students can learn at their own pace, repeating difficult material, or exploring concepts that interest them. This allows for more adaptive learning according to the needs of each student. The interactive learning experience provided by AR not only makes chemistry learning more fun but also allows students to be actively involved in exploring the learning material. In this way, AR changes the learning paradigm to be more dynamic and enables more effective teaching in the field of chemistry.

3. Increased understanding of abstract concepts

With the help of AR, chemical concepts that are difficult to understand conventionally can be illustrated more clearly. Students can see molecular interactions directly, strengthening their understanding of these concepts. In chemistry learning, many concepts are difficult to understand visually in a two-dimensional context. With AR, students can see and interact directly with molecular models in three dimensions. This allows them to understand molecular structures and inter-

molecular interactions more clearly, clarifying concepts that are difficult to understand in the conventional version. AR allows students to carry out simulations that are close to real conditions. They can see how molecules interact, change parameters, and see the impact directly. This allows a better understanding of how molecules work in chemical reactions or complex interactions. In chemistry, understanding context is crucial. AR can help students see how molecules or chemical reactions relate to their environment in real life. For example, how chemical reactions take place in everyday life or industry. By enabling clearer visualizations, realistic simulation experiences, and an experience-based approach, AR helps students strengthen their understanding of abstract concepts in chemistry. This changes the way students interact with course material and facilitates deeper understanding.

B. CHALLENGES OF USING AUGMENTED REALITY-BASED LEARNING MEDIA IN CHEMISTRY LEARNING

1. Infrastructure and Accessibility

AR implementation requires appropriate hardware and software. Not all educational institutions may have adequate infrastructure or the same accessibility to AR technology. The hardware required to access AR such as headsets, cameras, or special mobile devices is often expensive. Not all educational institutions can afford to purchase these devices in sufficient quantities for use by all students. Even if funding is available, the availability of AR devices in sufficient quantities could be a problem. Many institutions may not have access to the number of devices needed for use by an entire class or group of students. Quality AR software that suits chemistry learning needs may not always be widely available or have high subscription fees. The use of AR software requires adequate training for educators to integrate this technology into the curriculum.

These skills may not be available in all educational settings. Some AR apps require a strong internet connection to access content in real time or for large AR content downloads. Not all areas have stable and fast internet access. Some educational institutions may be located in areas that are underserved by digital infrastructure, making access to AR technology difficult. Addressing these challenges requires investment in technology infrastructure, increased accessibility, and training for teaching staff. Collaboration with external parties or technology developers can also help in providing more affordable solutions and wider access to AR technology in the educational environment.

2. Teacher Training

The use of AR in learning requires training for teachers to master the technology so they can integrate it into the curriculum effectively. Teachers need to understand how to use AR hardware such as headsets, cameras, or applications to create effective AR experiences. Mastering navigation and using tools in the AR virtual environment is an important skill so that teachers can direct students well. The training helps teachers integrate AR technology into existing curricula in a way that is relevant and appropriate to chemistry learning needs.

Training allows teachers to create or adapt AR learning content to suit teaching materials and learning objectives. Teachers need to understand how to guide students in using AR technology to maximize learning, ensuring focus on learning objectives, not just the technical aspects. Teachers need to be able to evaluate students' understanding of AR experiences and pay attention to assessment aspects in the context of this technology. Teachers need to be able to facilitate discussion, collaboration, and interaction between students in the context of using AR, making learning more dynamic. The ability to adapt to new technology and integrate it into existing learning strategies becomes important. Effective training for teachers in the use of AR technology not only helps them master the technical aspects but also helps them integrate this technology into their learning thereby creating a better learning experience for students.

3. Quality Content

Creating quality AR content for chemistry learning requires time, resources, and dedicated design skills. Creating content that is relevant and effective in learning requires quite a large investment. Creating accurate and adequate 3D models of molecules or chemical reactions requires high graphic design skills. Effective AR content requires variety to cover a wide range of chemistry concepts, from molecular structure to complex chemical reactions. Creating quality AR content takes quite a long time, especially for developing accurate 3D models and creating detailed animations. Invest in specialized software, powerful hardware, and human resources with AR design skills.

The process of developing AR content for chemistry learning involves continuous testing, refinement, and content development to ensure ever-increasing quality and relevance. Some educational institutions may choose to purchase or use AR content that is commercially available or from existing content providers. Creating quality AR content for chemistry learning does require quite a large investment in terms of time, labor, and finances. However, through this investment, the content produced can provide deep and valuable learning experiences for students.

CONCLUSION

Through this article, several key findings can be identified such as AR offers a great opportunity to improve students' understanding of abstract chemical concepts through three-dimensional (3D) visualization and interactive experiences. AR implementation requires adequate technological infrastructure and uniform accessibility but is still hampered by uneven hardware availability and connectivity in educational environments. The importance of training for educators in mastering AR technology so that they can integrate it effectively into the curriculum is a crucial factor in the successful implementation of AR in chemistry learning. Creating quality AR content requires a large investment in time, resources, and specialized design skills, which poses a barrier to developing relevant and effective content. Despite the challenges, the use of AR in chemistry learning promises a more interactive learning experience, clarifies difficult-to-understand concepts, and carries the potential to increase students' interest and understanding of chemistry material. By understanding the opportunities, challenges, and potential for using AR technology in chemistry learning, a clearer view can be found regarding the steps that can be taken to overcome obstacles and maximize the benefits of this technology in improving the quality of chemistry learning.

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