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An Exploratory Study of Augmented Reality for Teaching the Human Skeletal System at SMA Negeri 1 Suwawa

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ABSTRACT

The study addresses the challenges students face in understanding the human skeletal system and the need for innovative learning media. The research aimed to analyze the needs of students and teachers while evaluating the potential of Augmented Reality (AR) cards as a teaching tool. Conducted at SMA Negeri 1 Suwawa, Gorontalo Regency, the study employed a descriptive qualitative approach with data collection through observations, interviews, and student needs surveys. Findings revealed a strong interest among teachers in adopting AR-based media and high enthusiasm among students, with 84.2% recognizing its importance and 94.2% owning compatible devices. The results highlight the necessity for print-based learning media integrated with AR technology to deliver three-dimensional and realistic visualizations. This approach effectively bridges theoretical concepts and interactive representations, addressing comprehension challenges. The study concludes that AR-integrated learning tools have significant potential to enhance engagement and understanding in biology education, emphasizing the importance of their development and implementation.

INTRODUCTION

The rapid advancement of technology in the digital age has revolutionized various fields, including education. Modern educational systems are now designed not only to transfer knowledge but also to develop essential 21st-century skills, such as critical thinking, creativity, collaboration, and digital literacy (Trilling & Fadel, 2009). Technology has become an integral part of education, functioning as a component of the curriculum, a delivery platform, an instructional aid, and a tool for enriching the learning process. This shift has transformed education from a passive and reactive experience into an interactive and dynamic one (Raja & Nagasubramani, 2018). In both corporate and academic contexts, technology plays a vital role. In the corporate world, it is used to innovate workflows, while in academic settings, it fosters curiosity and enhances students' ability to grasp and retain complex concepts. By integrating technology into educational practices, traditional teaching methods can be complemented with modern tools that provide interactive and engaging learning experiences.

Biology is often perceived as an accessible subject (Hanzalova, 2019), but it also presents unique challenges due to its abstract topics. These include anatomical structures (Mitsuhashi et al., 2009), cellular processes (Jenkinson, 2018), and molecular genetics (Malacinski & Zell, 1996; Rotbain et al., 2006). Teaching these abstract concepts requires innovative approaches to sustain students' interest and motivation. Among these topics, the human skeletal system is particularly challenging, as it demands students to visualize complex structures and understand their functional relationships.

Observations conducted at SMA Negeri 1 Suwawa reveal significant challenges in students' understanding of the skeletal system due to the limitations of traditional learning materials.

Conventional tools, such as textbooks, static images, and videos, provide only two-dimensional representations, which fail to adequately capture the complexity of the skeletal system. These materials do not offer the interactivity needed to engage students or enhance their spatial awareness of anatomical structures. Furthermore, teachers face difficulties in conveying the dynamic and functional relationships between skeletal components using standard instructional methods. This often leads to student disengagement, as they struggle to visualize the three-dimensionality of bones and their interconnected functions. Without hands-on or interactive learning aids, students' comprehension is limited, making it harder for them to grasp abstract concepts like bone articulation, movement, and the skeletal system's role in the overall human body. Consequently, this situation highlights the need for innovative solutions, such as Augmented Reality (AR), to provide a more engaging and comprehensive learning experience.

Augmented Reality (AR) technology offers a potential solution to these challenges. Unlike Virtual Reality (VR), which creates entirely virtual environments, AR overlays digital content such as 3D models, text, videos, and audio onto the real world, seamlessly blending virtual and physical elements (Azuma, 1997). In the context of education, AR has been used to enhance traditional teaching methods by providing real-time, interactive learning experiences. For instance, AR-enabled textbooks and cards equipped with markers or triggers allow students to explore complex biological concepts, such as the skeletal system, in an engaging and tangible manner (Avila-Garzon et al., 2021). Learning using Augmented Reality aims to provide understanding as well as various phenomena occurring in the real world, with the expectation that it will have a positive influence on students. This positive influence includes changes in attitudes and behaviors, making students more concerned about the environment (Alvionita et al., 2021). Effective integration of AR in education requires appropriate pedagogical approaches, such as teacher-centered strategies to increase focus and retention (Astini, 2023) or problem-based learning (PBL) to connect abstract concepts to real-world applications (Savery, 2006). Although AR is widely employed in medical training, its application in high school biology is still limited (Kucuk et al., 2016; Yap et al., 2021). This gap underscores the need for further research to develop AR-based learning tools tailored to specific educational contexts.

Teaching abstract biological concepts, such as the human skeletal system, poses significant challenges for both students and teachers. Traditional methods often fall short in helping students visualize complex structures and understand their functional relationships. This gap highlights the need for innovative teaching tools that combine interactivity with visual engagement. To address this issue, the study aims to evaluate the feasibility of using Augmented Reality (AR) cards as a medium for teaching the skeletal system. By identifying the specific needs of students and teachers, the research seeks to bridge the divide between conventional methods and the demands of contemporary education. Additionally, it contributes to the integration of advanced technologies in classrooms, providing new solutions to enhance biology learning experiences.

MATERIALS AND METHODS

1. **Time and Place of Research**

   The study was conducted from August to September 2024 at SMA Negeri 1 Suwawa, located in Gorontalo Regency. The research focused on the topic of the human skeletal system as part of the Biology subject.

2. **Types of Research**

   This research employed a descriptive survey design aimed at analyzing the instructional needs of students and teachers in learning the skeletal system.

3. **Research Methods**

   The study utilized a mixed-method approach, integrating qualitative and quantitative data collection techniques to provide a comprehensive understanding of the needs and challenges in skeletal system learning.

4. **Population and Sample**

   The population consisted of students and teachers at SMA Negeri 1 Suwawa. The sample included 18 students who had previously studied the skeletal system and one biology teacher.

5. Research Procedure

The research procedure involved:

1) Identifying and preparing research instruments, including observation sheets, interview guidelines, and questionnaires.
2) Conducting observations during classroom sessions to document teaching strategies and learning challenges.
3) Interviewing the biology teacher to gather insights into instructional issues and potential technological interventions.
4) Distributing questionnaires to students to assess their perceptions, needs, and technological access.

6. Data Collection Techniques

Data were collected through three primary methods:

1) Observation: Classroom activities and teaching strategies were observed to identify existing challenges in delivering skeletal system materials.
2) Interviews: Semi-structured interviews were conducted with the biology teacher to gain insights into instructional difficulties and the potential of using technology-enhanced learning tools.
3) Questionnaires: Students were surveyed using structured questionnaires to understand their learning needs, perceptions, and access to supporting technologies.

7. Data Analysis Techniques

Data obtained from observations and interviews were analyzed qualitatively to identify recurring themes and challenges. Questionnaire responses were analyzed quantitatively using descriptive statistics to summarize student perceptions, preferences, and technological accessibility. This integrated approach aims to provide a detailed understanding of the instructional needs for teaching the skeletal system and the potential for integrating Augmented Reality (AR) tools into biology education.

RESULTS AND DISCUSSION

At this stage, challenges in the learning process and the need for Augmented Reality Cards as teaching media to aid in understanding concepts particularly the human skeletal system were identified. The results from observations, interviews, and questionnaires are presented in Tables 1, 2, and Figure 1.

Table 1. Observation Results on the Use of Learning Media by Biology Teachers

Observed Aspects	Observation Results
Learning Resources and Media	Learning Resources Used: Printed learning media, electronic books, LCD projectors, and slide presentations. 2. Learning Media: Visual media and audiovisual media (videos). 3. Other Findings: The absence of a human skeletal model (torso) to visualize concepts and the lack of 3D objects to help students understand the human skeletal system.
Learning Activities	Learning activities were conducted using presentation and discussion methods. In each session, one student group presented the learning material and facilitated a Q&A session. The teacher then provided reinforcement and clarified any incorrect answers.

Observations of the biology learning process at SMA Negeri 1 Suwawa revealed that the predominant teaching methods employed were discussion and presentation-based approaches. These methods provide opportunities for students to present professionally, enhancing their confidence and motivation to learn (Hernawati & Amin, 2017). They also allow students to articulate concepts systematically, helping them achieve a comprehensive understanding of the material (Rifa'i, 2012). However, despite their advantages, these methods have limitations, especially when students lack the necessary skills for scientific reasoning and verbal argumentation. In such cases, the learning objectives may not be fully achieved, highlighting the need for complementary strategies that address these shortcomings.

The observations also revealed issues related to the utilization of learning media. The biology teachers primarily used printed materials, electronic books, LCD projectors, and slide presentations. While visual aids and audiovisual media, such as videos, were also incorporated, these tools were found to be insufficient in addressing the learning needs of students. Notably, the absence of physical teaching aids such as a human skeletal torso made it difficult for students to visualize and comprehend the structure and functions of the skeletal system. The lack of three-dimensional models further exacerbated this issue, limiting students' ability to grasp abstract biological concepts effectively.

Additionally, while videos were employed as supplementary resources, they were often perceived as monotonous and failed to sustain student interest. The reliance on such static media restricted the potential for active learning and engagement. This aligns with existing research that emphasizes the need for more dynamic and interactive teaching aids to enhance students' cognitive understanding, especially in complex subjects like biology (Damopolii et al., 2022; Fitria, 2023). The discussion and presentation-based teaching methods, although widely regarded as effective for fostering student participation, also have inherent limitations. These methods rely heavily on students' verbal and analytical skills, which can pose challenges for learners who struggle in these areas. Additionally, they lack the ability to provide concrete, visual representations of abstract concepts, further highlighting the need for improved learning media.

To address these challenges, integrating innovative learning media such as Augmented Reality (AR) can provide a significant solution. AR offers a unique opportunity to visualize and interact with three-dimensional objects, effectively bridging the gap between theoretical knowledge and practical understanding. By incorporating AR-based tools into biology lessons, educators can offer students more engaging and interactive learning experiences, addressing the limitations identified in the current methods and media.

The observations from SMA Negeri 1 Suwawa underscore the limitations of existing learning media and teaching methods in biology education. While discussion and presentation-based approaches have their strengths, their effectiveness can be significantly enhanced through the integration of innovative learning media such as AR. Such tools can provide the visual and interactive support needed to help students better understand complex biological concepts, paving the way for more effective and engaging learning experiences.

Table 2. Interview Results with the Biology Teacher

Question Aspects	Biology Teacher's Responses
Understanding of Augmented Reality-Based Learning Media	The teacher had heard of Augmented Reality-based learning media but had never used it due to a lack of knowledge on how to create or use such technology.
Interest in Using Augmented Reality-Based Learning Media	The teacher was very interested, as it would offer a new learning experience for students.
Expectations for Using Augmented Reality-Based Learning Media	Not only to display visuals in the form of 3D objects but also to include text annotations and even video content.
Accessibility of Augmented Reality-Based Learning Media	The use of Augmented Reality-based learning media is highly feasible at SMA Negeri 1 Suwawa, as students often use smartphones during lessons.

The interviews conducted with the biology teacher at SMA Negeri 1 Suwawa revealed significant insights regarding the potential use of Augmented Reality (AR)-based learning media. These findings highlight that while the teacher has a basic understanding of AR media, its implementation in teaching practices has yet to be realized.

Teacher's Understanding of AR-Based Learning Media

The teacher mentioned having heard of AR-based learning media but lacked in-depth knowledge of how to create or utilize the technology. This indicates a gap between the potential of AR technology to enhance learning and the technical expertise of teachers in leveraging it. Such a disparity reflects a common trend in education, where technological advancements often outpace

educators' readiness to adopt them (Hermawan et al., 2020). Therefore, training and guidance are essential to help teachers effectively integrate AR-based media into their teaching strategies.

Teacher's Interest in AR-Based Learning Media

The teacher expressed a strong interest in AR media, viewing it as a tool that can offer students a novel and engaging learning experience. This enthusiasm underscores the teacher's recognition of the importance of innovation in instructional media to enhance teaching quality. AR media stands out for its ability to present material interactively and engagingly, which can significantly boost students' motivation to learn (Billinghurst, 2002). Consequently, this interest serves as a solid foundation for integrating AR technology into biology instruction.

Teacher's Expectations for AR-Based Learning Media

The teacher hopes that AR media not only displays 3D objects but also includes descriptive texts and supporting videos. This expectation highlights the need for learning media that is not only visually appealing but also informative and comprehensive. The combination of 3D object visualization, descriptive text, and videos can help students grasp concepts more deeply, particularly abstract topics such as the human skeletal system. This approach aligns with Mayer's multimedia theory (2005), which emphasizes that effective learning occurs when visuals, text, and animations are combined to convey information.

Accessibility of AR-Based Learning Media

The teacher indicated that implementing AR-based media is highly feasible at SMA Negeri 1 Suwawa, as students are already accustomed to using smartphones during learning activities. This situation presents a significant opportunity to incorporate AR as a learning medium, given that the required devices are readily available. Integrating smartphones into the learning process simplifies students' access to AR-based educational content and supports more interactive and flexible learning (Wahyuni et al., 2021).

Based on the interview findings, it is evident that the teacher exhibits a strong enthusiasm for AR-based learning media. However, the technology's implementation faces technical challenges. To address these challenges, teachers need targeted training to acquire the skills to design and use AR media effectively in teaching, schools should provide the necessary tools and platforms to support the development of AR-based media, and AR media should be incorporated into the curriculum as part of an interactive, contextual teaching strategy. By utilizing AR-based media, biology learning processes especially for complex topics such as the human skeletal system can become more effective, engaging, and interactive, fostering better learning outcomes for students.

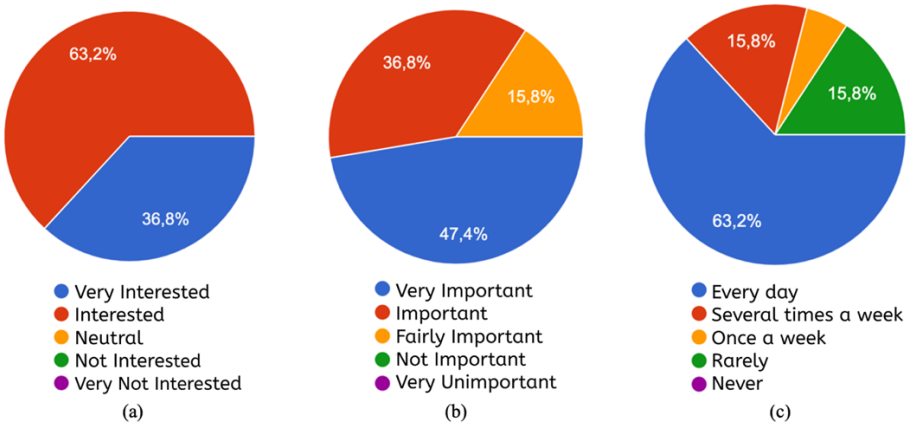

Figure 1. Results of Student Questionnaires on the Use of Augmented Reality Cards: (a) Interest in using augmented reality learning media, (b) Importance of using augmented reality learning media, and (c) Access to technology for learning purposes.

The analysis of student questionnaire responses underscores the significant potential of Augmented Reality (AR) cards as an innovative learning medium. The unanimous interest (100%) among students in using AR cards indicates their enthusiasm for exploring novel educational methods. This enthusiasm stems from the novelty of AR cards, which differ from traditional learning resources such as textbooks and e-books. Current learning methods that rely heavily on text-based resources tend to disengage students, as these methods lack interactive and immersive elements. Mauludin et al. (2017) emphasize that students often lose motivation when required to study using static textbooks, particularly if they are not complemented with videos or other dynamic content. The preference for AR cards highlights a shift in students' expectations, aligning with contemporary trends where learners demand visually engaging and interactive materials to maintain focus and foster understanding. Furthermore, 84.2% of students recognize the importance of integrating AR-based learning media into their educational experience. This recognition signals that students are not only eager to adopt new tools but also aware of the limitations of existing methods. The dissatisfaction with static resources suggests a broader call for educational innovations that bridge the gap between abstract concepts and tangible understanding.

The widespread use of smartphones among students provides a practical advantage for implementing AR-based learning tools. With 94.2% of students frequently using smartphones for learning purposes, AR technology can be seamlessly integrated into their study routines. The accessibility of smartphones ensures that students are equipped to utilize AR applications without requiring significant infrastructural changes or additional financial investments. This accessibility reinforces the feasibility of AR adoption in educational settings, making it a practical solution for enhancing engagement and comprehension. The inherent familiarity with smartphones among students reduces the learning curve associated with adopting new technology, allowing educators to focus on the content and pedagogical strategies rather than technical challenges.

Education is uniquely suited for the application of AR technology due to its ability to blend real-world and virtual elements. AR facilitates a more interactive and immersive learning experience, addressing the limitations of traditional text-based methods. According to Billinghurst (2002), AR's ability to integrate dynamic visualizations into textbooks or standalone learning applications enhances the richness of information without overwhelming students with excessive text. In the context of biology education, AR offers unparalleled opportunities to present complex topics, such as the human skeletal system, in a more accessible and engaging manner. For instance, AR can render 3D models of anatomical structures, enabling students to interact with and explore these models from various angles. This interactivity aids in bridging the gap between theoretical knowledge and practical understanding, fostering deeper comprehension. Lee, et al (2004) highlight that 3D animations effectively demonstrate intricate processes, making it easier for educators to explain and for students to grasp challenging concepts.

Despite the promising potential of AR-based media, there remains a significant need for continued development to ensure that such tools are effective, user-friendly, and widely accessible. Current media resources often fail to meet the diverse needs of students, underscoring the importance of tailoring educational innovations to accommodate various learning styles. The high adoption rate of smartphones among students provides an impetus for integrating AR technology into mainstream education. By leveraging this existing infrastructure, educational institutions can introduce AR-based tools without imposing additional financial or technical burdens on students or teachers. However, successful implementation requires collaboration between educators, developers, and policymakers to create resources that are pedagogically sound, technically robust, and easily adaptable to different learning environments.

CONCLUSION

The findings reveal that traditional teaching materials, such as textbooks, e-books, and videos, are insufficient in helping students understand abstract concepts due to the lack of 3D models or physical aids. Both teachers and students expressed strong interest in using AR-based media, with teachers recognizing its potential to enhance learning experiences and students viewing it as an

engaging and effective tool for understanding complex topics. Additionally, the widespread use of smartphones among students makes AR-based tools feasible for integration into the classroom, offering an opportunity to improve learning with minimal infrastructural changes.

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