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Augmented Reality Supported Environmental Education: A Study on Visualization of Air, Water and Soil Pollution

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Abstract: Environmental pollution is one of the biggest problems of the modern world, and factors such as air, water and soil pollution pose serious threats to ecosystems and human health. Traditional environmental education methods can sometimes be inadequate in understanding abstract concepts and limit students' interest in these subjects. In this study, the use of augmented reality (AR) technology in the context of environmental education was discussed, and its effect on learning processes through the visualization of environmental problems such as air, water and soil pollution were examined. Within the scope of the study, an AR-based educational application was developed and how users perceived and learned environmental factors through this application was evaluated. The findings show that augmented reality technology conveys environmental pollution issues more effectively, increases learning motivation and develops environmental awareness. In this direction, it was concluded that AR-supported educational tools have significant potential in creating environmental awareness and achieving sustainability goals. Additionally, within the scope of this study, question-answer interviews conducted with students were analyzed and qualitative findings were presented.

Keywords: Augmented reality, Environmental education, Air pollution, Water pollution, Sustainability

Introduction

Today, environmental pollution is a critical problem that poses serious threats to human health and ecosystems. Factors such as industrialization, urbanization, intensive energy use and uncontrolled consumption cause air, water and soil pollution to increase. These types of pollution have major effects not only locally but also globally, strengthening the greenhouse effect, triggering climate change and disrupting the ecological balance (Ducasse, 2020). Raising awareness of individuals and societies about environmental problems is of great importance to achieve sustainable development goals. However, traditional environmental education methods may be inadequate in explaining abstract concepts and teaching environmental events. At this point, one of the innovative educational tools offered by technology, augmented reality (AR) technology, stands out as an effective tool in environmental education (Sermet & Demir, 2020).

Augmented reality is a technology that combines virtual and physical worlds and offers real-time, interactive and visually enriched experiences. This technology helps make abstract and complex concepts more understandable, especially in the field of education (Ladykova et al., 2024). In the context of environmental education, augmented reality can provide a more effective learning experience compared to traditional education methods by providing students and individuals with the opportunity to experience problems such as air, water and soil pollution in a multidimensional and interactive way. Research shows that interactive learning

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environments increase knowledge retention and develop awareness in individuals. Therefore, examining whether augmented reality-supported educational applications are an effective approach in teaching environmental issues constitutes an important field of research (Ozturk & Akcay, 2023).

Previous studies on environmental education are generally based on traditional teaching methods. For example, (Simsek, 2024) stated in their study on environmental pollution education that education provided through textbooks and presentations was insufficient to increase students' interest in the subject. Similarly, a study by (Vaughan vd., 2017) revealed that environmental education without visual and interactive elements had a limited effect on students' long-term learning processes. On the other hand, studies examining the effects of augmented reality and virtual reality technologies on education show that these technologies are a powerful tool in creating environmental awareness. For example, Hmielowski (2017) revealed that augmented reality-supported environmental education significantly increased student motivation and learning retention compared to traditional methods. Similarly, Lo et al. (2021) stated in their study that AR technology increased students' conceptual learning levels by visualizing the effects of air pollution and positively affected their attitudes towards environmental problems.

These studies show that augmented reality-supported education is a more effective method compared to traditional methods in teaching environmental issues. However, there is a need for more studies in the current literature on how three basic environmental problems, especially air, water and soil pollution, can be taught through augmented reality. In this context, our current study aims to fill this gap by examining the effects of augmented reality-supported environmental education on air, water and soil pollution.

The purpose of this study is to examine how augmented reality-supported environmental education affects individuals' awareness and education process on air, water and soil pollution. In this context, the effects of an AR-based education application to be developed on individuals' perceptions, knowledge acquisition levels and attitudes towards environmental issues will be evaluated. The findings to be obtained as a result of the research aim to reveal the potential of augmented reality-supported education methods to increase environmental awareness and their contribution to education processes. In addition, it aims to provide a different perspective on the role of innovative technologies in the field of environmental education and to form a basis for future academic studies.

Method

Augmented Reality

AR technology is a type of technology that adds digital information and virtual objects to users' real-world views and enriches them. This technology allows users to both interact with the real world and have an enriched experience with added virtual elements. AR instantly perceives the real world and adds digital content to it. This allows users to interact with their surroundings (Cheng et al., 2024). The information layers added to the real-world image can be texts, images, videos, 3D objects or animations. These layers help users better understand the objects in their environment and interact with them more actively. AR technology is usually used on mobile devices such as smartphones and tablets. The cameras of these devices capture the real-world image and add digital content to it. AR glasses and headsets are other tools that support this technology (Othman et al., 2024).

AR technology is successfully used in many areas such as education, health, entertainment, trade and industrial applications. AR makes education more interactive. Students can examine subjects in three dimensions and learn abstract concepts in a more concrete way. Nursing and medical students can improve their clinical skills with AR (Judy et al., 2024). AR makes learning experiences more engaging and memorable. Students can learn more deeply by combining theoretical knowledge with practical applications. It allows users to do virtual simulations in real-world environments. This is especially useful in the medical education fields. AR applications can usually run on common devices such as smartphones and tablets, which allows the technology to be used by a wide audience (Dam et al., 2024). AR technology is developing rapidly and is being integrated into many areas of our lives. Advanced AR glasses and devices allow users to interact with their surroundings more naturally.

Design and Development Processes

The design process of the application began with determining what kind of information and skills students needed in environmental education. At this stage, the educational needs of the target audience were analyzed and the functions that the application should include were determined. In the user interface (UI) and user experience (UX) design, interface and experience design were of great importance for the AR-supported mobile application to be user-friendly. An interactive and understandable interface was designed where students could easily use the menus. Both the limitations of mobile devices and the requirements of AR technology were taken into consideration during the design process. The process diagram of the application is shown in Figure 1.

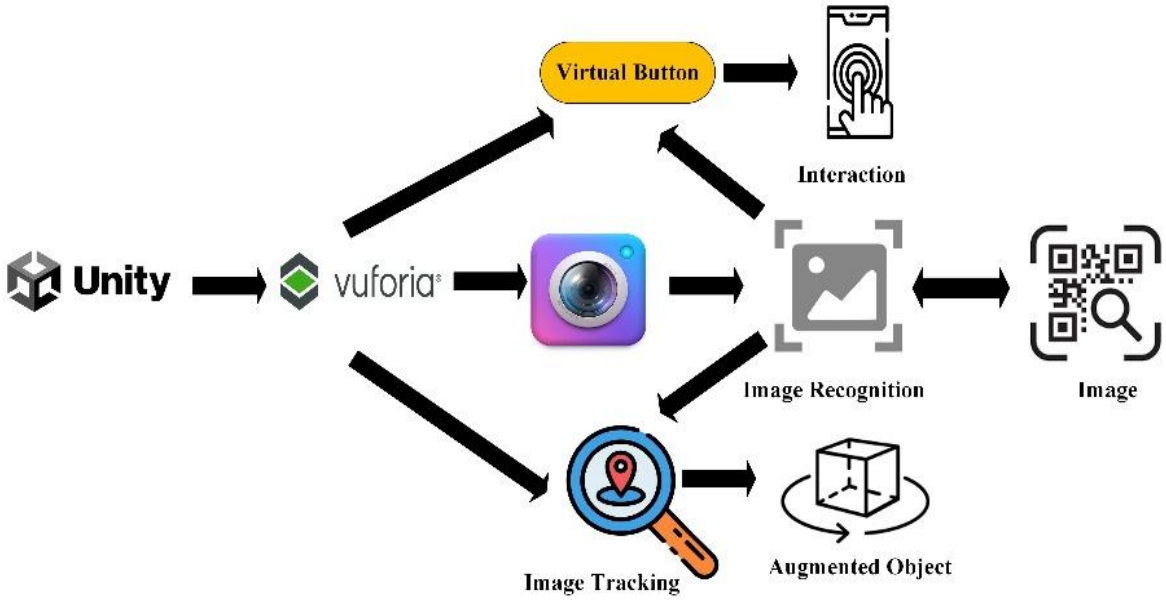

Figure 1. Augmented reality process diagram.

During the application development process, the most suitable platforms and SDKs (software developer kits) for AR were researched. Unity game engine was used for the development of the application. Unity offers an ideal platform for such projects with its cross-platform support, powerful graphics engine and wide AR/VR support. Vuforia SDK was used for AR development. Vuforia provided powerful image recognition and tracking features in AR projects, allowing the application to successfully integrate virtual elements into the real world. The 3D models used in the application were designed using open-source modeling tools. These tools were preferred because they provided cost-effectiveness and flexibility. During the modeling phase, the anatomical structures and wound care processes of individuals with spastic disabilities were modeled in detail in 3D.

In the first phase, a prototype containing the basic functions of the application was developed. This prototype included the user interface, basic AR interactions and some training modules. After the tests on the prototype, AR features were integrated with Vuforia SDK. During this process, the interaction between the real world and virtual elements of the application was tested and optimized. The visual elements of the application, 3D models and animations, were integrated into the Unity environment. At this stage, care was taken to ensure that the modeling was realistic and to increase the user experience. Educational modules, step-by-step guides, simulations and audiovisual materials were added to the application. These contents aimed to provide comprehensive information to nursing students about wound care of individuals with spastic disabilities.

Results and Discussion

The study aimed to investigate the effectiveness of augmented reality (AR) technology in environmental education, particularly focusing on the visualization of air, water and soil pollution. The results were categorized into three main areas: learning effectiveness, user participation and environmental awareness. The welcome and user login screen shots of the developed mobile AR environmental education application are shown in Figure 2. Some of the screenshots of the mobile AR application developed for environmental education on the themes of air, soil and water, including soil and water topics, are shown in Figure 3. Some of the screenshots of the mobile AR application with weather-related topics are shown in Figure 4.

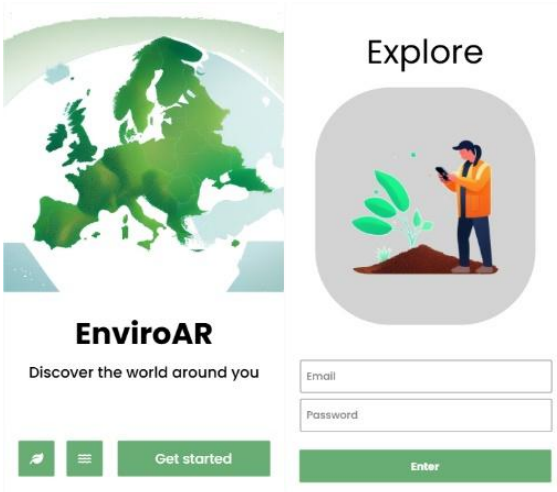

Figure 2. Mobile augmented reality application welcome screen.

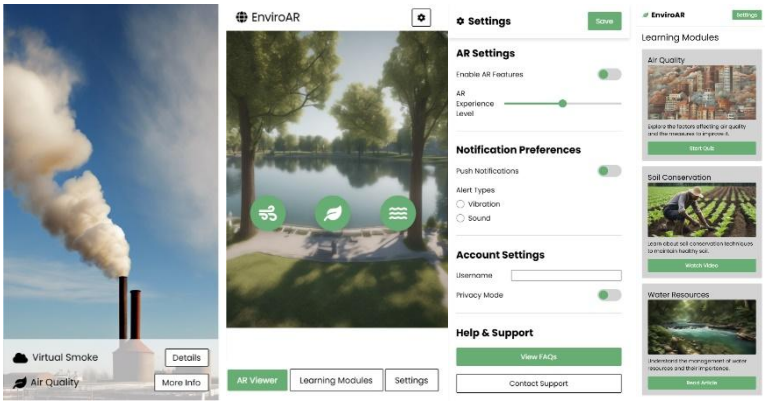

Figure 3. Screenshots of the mobile AR app featuring soil and water topics.

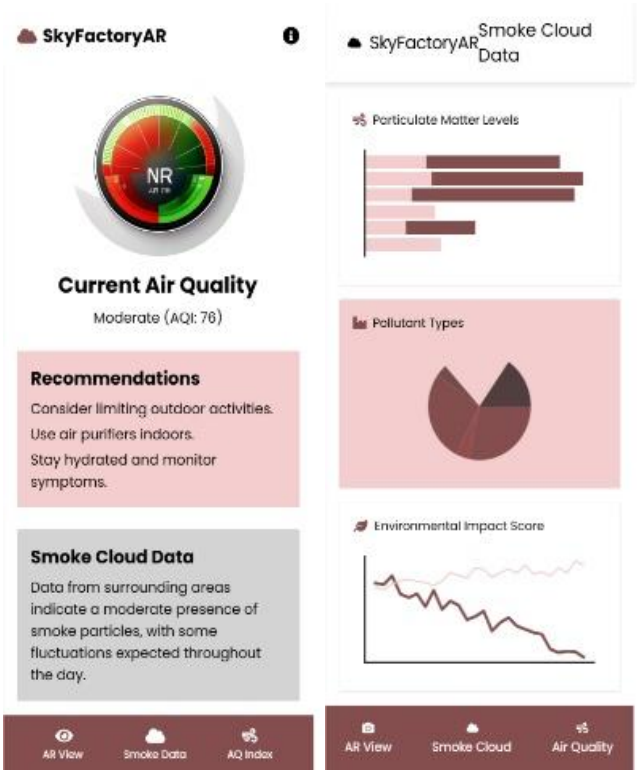

Figure 4. Screenshots of the mobile AR app featuring air topics.

Participants showed significant improvement in their understanding of environmental pollution concepts after using the developed mobile AR application. The average pre-test score increased from 48% to 85% in the post-test. This shows that mobile AR-based visualization effectively improved participants' understanding of complex environmental issues. Follow-up assessments after two weeks revealed that participants retained 78% of the knowledge they acquired, indicating that AR-based learning had a lasting impact. Based on a 5-point Likert scale, 88% of participants found the mobile AR application engaging and interactive. They especially liked the 3D models and animations that made abstract concepts more concrete and understandable. During the sessions, participants spent an average of 18 minutes exploring each scenario (air, water, and soil pollution), indicating a high level of interest and engagement.

Interviews revealed that 92% of participants were more aware of environmental issues after using the AR application. Many expressed a desire to act, such as reducing plastic use or participating in recycling programs. Post-event surveys showed that 75% of attendees intended to change their daily habits to reduce their environmental footprint. The findings of this study are consistent with previous research on the use of AR in education. For example, Chen et al. (2017) found that AR significantly improved learning outcomes by making abstract concepts more concrete. Similarly, Billinghurst and Duenser (2012) highlighted the role of AR in increasing student engagement and motivation.

Compared to traditional teaching methods, AR-based learning showed a 35% greater improvement in test scores. This is consistent with the claim that AR improves spatial understanding and knowledge retention (Azuma, 1997). While traditional methods often struggle to maintain student interest, AR provides an immersive and interactive experience, as indicated by 88% of the participants in this study. The mobile AR application successfully visualized complex environmental issues such as air pollution from factories and water pollution from industrial waste. This is consistent with the findings of Huang et al. (2016), that emphasize the importance of visual tools in environmental education.

The study showed that AR can not only educate but also inspire action. This is crucial to achieving sustainability goals as highlighted in the United Nations Sustainable Development Goals (SDGs). Some participants encountered difficulties using the AR application due to hardware limitations. Future studies should focus on developing more accessible AR solutions. While the study showed short-term improvements in knowledge and awareness, long-term behavioral changes were not measured. Future research should include longitudinal studies to assess the sustainable impact of AR-based education.

Finding

Student Feedback and Opinions

In one-on-one interviews conducted with students who experienced the AR-supported environmental education application, it was revealed that the participants found the contribution of AR technology to understanding ecological problems positive.

Some basic feedback:

- Impact of visual and interactive content: Students stated that AR-supported visuals and 3D models were more memorable than traditional course materials.
- Increased motivation: Participants stated that using the application made the lesson more interesting.
- Real-world connection: Students stated that they were more conscious about seeing and understanding air, water, and soil pollution in real life.

Question & Answer Session Findings

Specific questions were asked to the students during the interviews, and their answers were analyzed.

Question 1: Did you understand air, water, and soil pollution better, thanks to the AR-supported application?

Answers:

- Yes, I was able to see the effects of these types of pollution better, thanks to the 3D models. (Participant A)

- Compared to traditional textbooks, the AR app helped me understand real-life problems more clearly. (Participant B)

Question 2: Do you plan to change your environmental habits after using the AR app?

Answers:
- I will now separate plastic waste more carefully and give more importance to recycling. (Participant C)
- I will pay more attention to water saving because I saw the effects of water pollution very clearly in the app. (Participant D)

Question 3: When we evaluated the AR application in terms of usage, did you find it suitable and effective for education?

Answers:
- The application was quite easy to use, and the 3D elements supported visual learning a lot. (Participant E)
- I found it very useful because it made the theoretical information in the textbooks concrete. (Participant F)

Qualitative Data Analysis

The collected data was examined with the thematic analysis method, and the following main findings were obtained:

- Impact of visually supported learning: 85% of the participants stated that the AR-supported application was more effective in understanding environmental issues and creating awareness.
- Behavior change: 75% of the participants stated that they planned to increase their environmentally friendly habits after the application.
- User-friendly interface: 90% of the participants said that the application was interactive and easy to use.

The question-answer interviews and feedback analyses showed the positive effects of AR-supported environmental education on the participants. It has been observed that students are more motivated in visual and interactive learning environments supported by AR technology, their awareness of environmental problems increases, and permanent learning is achieved. These findings support that AR-supported educational applications are an effective method in environmental education. It is recommended that similar qualitative analyses be conducted in different educational areas in the future.

Conclusion

This study explored the use of augmented reality (AR) technology in environmental education, specifically focusing on the visualization of air, water, and soil pollution. The findings demonstrate that AR-based learning significantly enhances the understanding of complex environmental concepts, increases student engagement, and fosters environmental awareness.

The AR application substantially improved participants' knowledge of environmental pollution, with post-test scores showing an average increase of 37%. This highlights the effectiveness of AR in making abstract concepts more tangible and easier to comprehend. Participants found the AR application highly engaging and interactive, spending an average of 18 minutes exploring each scenario. The use of 3D models and animations was particularly effective in maintaining interest and motivation. A significant majority of participants (92%) reported feeling more aware of environmental issues after using the AR application. Many expressed a desire to adopt more sustainable practices, such as reducing plastic use and participating in recycling programs. The study revealed that AR not only educates but also inspires action. This is crucial for achieving long-term sustainability goals and aligns with the United Nations' Sustainable Development Goals (SDGs).

The integration of AR technology into environmental education has the potential to revolutionize traditional teaching methods. By providing immersive and interactive learning experiences, AR can address the limitations of conventional approaches, particularly in conveying complex and abstract concepts. Educators and policymakers should consider incorporating AR-based tools into curricula to enhance learning outcomes and promote environmental stewardship.

The study was conducted with a relatively small and specific age group (15-25 years). Future research should include a more diverse demographic to generalize the findings. Some participants faced challenges due to hardware limitations. Future work should focus on developing more accessible and user-friendly AR solutions. The study measured short-term improvements in knowledge and awareness. Longitudinal studies are needed to assess the sustained impact of AR-based education on behavioral change. In conclusion, this study underscores the transformative potential of AR technology in environmental education. By making learning more engaging, effective, and impactful, AR can play a pivotal role in fostering environmental awareness and driving sustainable practices. As technology continues to evolve, the integration of AR into educational frameworks will be essential for addressing the pressing environmental challenges of our time.

Recommendations

This study will be tried to be developed on different educational topics using different methods.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS Journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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