A WEARABLE AUGMENTED REALITY APPLICATION FOR 5R PLASTIC WASTE POLLUTION EDUCATION

KOUBAOGUO

Dr.Rimaniza Zainal Abidin

Faculty of Information Science & Technology, The National University of Malaysia, 43600 UKMBangi, Selangor, Malaysia

ABSTRACT

Plastic pollution poses a severe environmental threat due to its nonbiodegradable nature, impacting ecosystems, wildlife, and human health, but sustainable management through the 5R principles: Refuse, Reduce, Reuse, Recycle, and Recover can mitigate its harmful effects. Previously several awareness campaigns are going on for plastic waste pollution education. However, most of the general public still lacks engaging and impactful educational tools that involve them in adopting sustainable practices. The objective of this project is to develop a wearable Augmented Reality (AR) application that provides an interactive and immersive learning experience to enhance public awareness of plastic pollution and its environmental impact. The application will integrate the 5R practices in a wearable augmented reality platform that offering users practical and engaging ways to adopt sustainable waste management practices. By simulating real-world impacts due to plastic waste and suggesting doable alternatives, GreenLens AR is will be produced to measures effectiveness of the wearable AR educational approach in improving user engagement, knowledge retention, and behavioral changes toward reducing plastic waste. This project follows the Waterfall methodology, where requirement analysis, interface and scenario design, development and content integration, testing, and deployment are done in a structured manner. The key features to be implemented in the application are AR-enabled interactive learning modules, quiz and real-time feedback mechanisms. The project thus contributes to the global sustainability movement, as it lets people understand how the 5Rs interlink and help to take appropriate action toward reduction in plastic wastes. GreenLens AR puts together recent developments in wearable AR with a structured learning functionality to act as a bridge between knowledge and action, and to amplify positive effects on the conservation of natural resources. The testing phase was targeted at three vital objectives, namely validating the functional correctness of the system—particularly scene changes, interactions among objects, and responsiveness of the interfaces; determining 5R-related learning material usability and intelligibility; and employing TAM to

gain understanding of user acceptance in terms of perceived usefulness, ease of use, and behavioral intention.

Keywords: Gamification, Usability, Augmented Reality

1.0 INTRODUCTION

RESEARCH BACKGROUND

Augmented reality (AR) is the integration of digital information with the user's environment in real time. Unlike virtual reality (VR), which creates a totally artificial environment, AR users experience a real-world environment with generated perceptual information overlaid on top of it (Alexander S. Gillis 2018). Using AR to Enhance Environmental Awareness AR provides a unique platform for environmental education by making abstract issues, such as pollution or climate change, visually accessible and immersive. (Yuen, S. C., Yaoyuneyong, G., & Johnson, E. 2011).

This technology allows users to interact with realistic simulations, showing the impact of plastic pollution on marine life or how waste accumulates in urban settings. By enabling users to visualize the consequences of environmental neglect, AR can encourage them to adopt sustainable practices, such as the 5R principles (Refuse, Reduce, Reuse, Recycle, Recover). Additionally, AR-driven scenarios can demonstrate practical actions individuals can take to reduce plastic use, making environmental conservation more approachable and actionable.

In summary, AR technology stands out as an effective tool in promoting environmental awareness by combining visual impact with interactive learning. Its ability to highlight previously invisible environmental issues can be critical in raising public awareness, particularly about the plastic catastrophe. By using augmented reality for environmental education, we may motivate behavioral change and provide users with knowledge about sustainable behaviors, thereby contributing to a larger effort to safeguard the environment.

Plastic pollution remains one of the most pressing environmental issues, with over 8 million tons of plastic waste entering oceans annually. Despite awareness campaigns, public understanding and engagement in reducing plastic waste are limited. Traditional educational approaches often fail to effectively convey the urgency of plastic pollution or promote the adoption of sustainable practices like the 5R principles. The lack of impactful, interactive educational tools is a barrier to fostering meaningful public awareness and action.

To address this gap, an AR-based application is proposed to provide an interactive platform for environmental education focused on reducing plastic pollution. By using AR technology, users can engage with simulated scenarios that depict the impact of plastic waste, making the issue both visible and personal. The application will incorporate the 5R principles, presenting users with practical, actionable steps to reduce plastic consumption and waste. This approach aims to go beyond traditional educational materials, making environmental awareness education both immersive and impactful.

2.0 LITERATURE REVIEW

AR is being recognised increasingly as a good tool in education for making learning more interactive. In the wake of increasing environmental problems, such as plastic pollution, the need for effective public participation in sustainability principles calls for an innovative approach using AR. This study investigates the use of AR technology to develop public awareness related to environmental conservation through an interactive platform that educates users on the effects of plastic pollution and facilitates more sustainable behavior. This project will try to make the most of the immersive potential offered by AR for communicating the negative consequences brought about by plastic wastes and empowering sustainable behaviors. Imagine that the user puts on HoloLens 2 and enters a virtual ocean world contaminated by plastic waste. They witnessed with their own eyes the bleaching of corals due to plastic pollution, Marine life trapped in plastic waste, and could even "touch" these pollutants to feel their damage to the ecosystem. This immersive experience not only enhances users' emotional resonance but also promotes the emergence of environmentally friendly behaviors. Studies show that augmented reality technology has significant advantages in environmental education. Studies by Feldmann, M. et al. (2024) Players collect garbage in the virtual underwater world. Although they cannot completely remove the pollution in the end, this experience emphasizes the importance of pollution prevention and enhances users' environmental awareness. 13 In addition, elements such as gamification mechanisms like points and quiz can increase user engagement and sustainability. For instance, the Joulebug app by Grigorios L. Kyriakopoulos (2023) has achieved positive results by integrating games, social media and educational tools to encourage users to participate in sustainable activities. In Malaysia, the VR game developed by Sunway University was showcased at the United Nations' "Rock the Goals" event. By allowing users to experience the consequences of environmental destruction through virtual scenes, it has stimulated the public's environmental awareness. In conclusion, mixed reality technologies such as HoloLens 2 have transformed environmental education from passive acceptance to active participation through immersive experiences and gamification mechanisms, stimulating users' environmental awareness and behaviors, and opening up a new path for sustainable development education.

3.0 METHODOLOGY

The rapid development in augmented reality opened new paths for developing interactive and immersive educational tools, especially with regard to critical environmental issues awareness. The "Environmental Awareness Education AR Application" uses AR to make learning of the 5Rs that reduce plastic pollution enjoyable and effective: Refuse, Reduce, Reuse, Recycle, and Recover. The application design will be developed based on a structured approach: requirements analysis, definition of functional and non-functional requirements, system modeling, and database development. By the use of dynamic media, this application will fill the lacuna left by conventional learning methods in order to achieve behavioral change and enhance understanding with regard to sustainable practices. For developing an application for its targeted audience, it undergoes an intensive analysis of requirements at the end-user level; moreover, hardware, software, and security are considered important segments in system requirements. System modeling represents the working functionalities and end-user interaction diagrams, while overall database architecture reflects how content and performance will be managed.The primary objective is to deliver an accessible and effective learning experience driven by AR technology. This chapter presents the results and analysis of the GreenLens AR application for environmental awareness education, examining its impact on users' understanding of the 5R principles and plastic waste management. Through interface evaluations, hierarchical design, and system testing, it explores how the application fosters interactive learning and promotes sustainable behaviors. Additionally, user 27 engagement, technical performance, and feedback are analyzed to identify areas for future improvement. It started with the identification of very specific requirements regarding education content and interactive features of AR. Then came detailed design, which outlined the user interface, animations, and representation of the 5R principles. Actual development to implement these designs using Unity and AR tools came next. While this included rigorous testing to ensure that the application worked seamlessly across devices, the last stage, maintenance, involves taking feedback from users to incorporate and fine-tune the software upon its release. This sequential approach ensures that at every stage, everything is covered, minimizing risks and meeting project goals effectively.

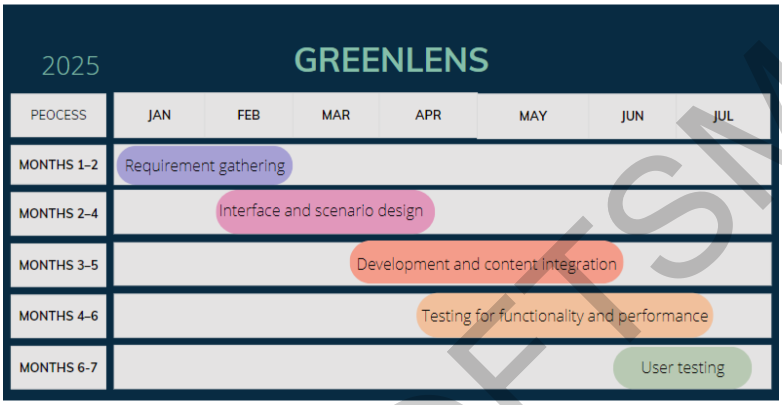


*Figure 1:*Implementation schedule

3.1 User Needs List

User Problem

The user wants to know whether this program will really be interesting compared with the traditional educational methods.

Is this application easy for beginners to operate and friendly to users who have not been exposed to AR technology.

User Problem Solution

The e-learning platform will teach the 5R's principles in an entertaining, interactive format, where activities are created that will encourage students to participate in learning; it also embeds assessment tools where users answer questions on the 5R's and review their progress. It ensures high priority in security since personal information is only granted to the authorized persons. It allows students to take part in the activities of simulation with an aim to apply principles 5R in practical exercises in a more entertaining manner than reading from the book, it is very friendly to novice users. The very simple operation interface is convenient for users to operate.

3.2 Conceptual Model Design

Testing was conducted both in emulator and on real HoloLens 2 hardware with 3 evaluators and 20 student participants. Users explored the AR content, triggered voice/tap commands, and responded to quiz panels. The TAM questionnaire was completed directly after testing.

All major functionalities of MyGreenLens passed detailed functional and usability testing, confirming the system's stability and fullness of main features. The TAM-based evaluation also supported the apps' high level of user acceptance, with positive results in perceived usefulness, ease of use, and intent to continue system use. Some of the usability problems related to interaction flow were addressed by enhancing user interactivity through the use of MRTK2 utilities, such as improved gaze and hand input handling. In addition to native voice-command scene switching, there was a secondary feature of button-switching, giving users a second way to switch between learning scenes. Likewise, the quiz page was also improved by adding a continue manually option to the next question as an effort towards giving users more control over learning pace. These changes made the user interface smoother and more enjoyable, and the educational value of the application and its usability in learning environments focused on sustainability were improved. These updates synchronized and harmonized with the user interface more effectively, justifying the value of learning within the application and implementation into future sustainable learning systems.

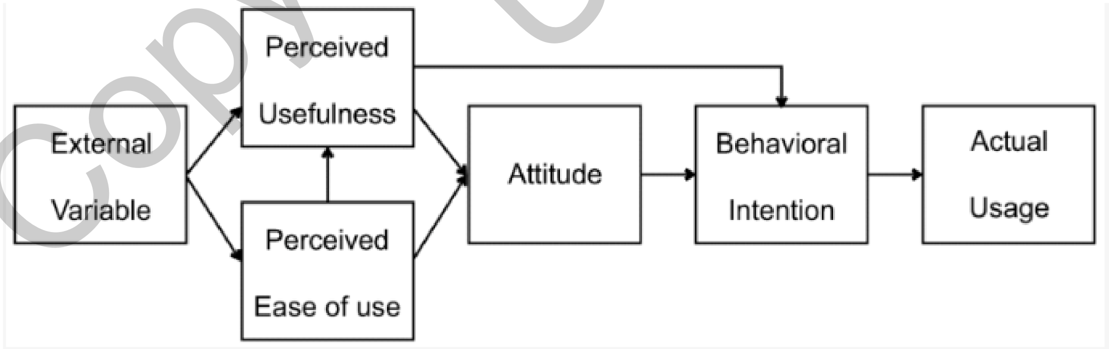


Figure 2: Technology Acceptance Model (TAM) by Davis (1989).

4.0 RESULTS

During functional testing, the MyGreenLens application successfully met all key requirements through five primary test cases. These included interactions such as tapping 3D objects, switching between panels, activating voice commands, and completing quizzes. Although slight delays in scene responses were noted in brighter environments, these were resolved by adjusting the object layer configuration within the MRTK settings. No critical functional issues or crashes were observed, indicating the app runs reliably in typical usage scenarios. To evaluate user acceptance, a TAM questionnaire was administered to 15 students following hands-on testing. The results show that the average score for Perceived Usefulness (PU) was 4.5, suggesting that users considered the system effective in enhancing environmental understanding. The Perceived Ease of Use (PEOU) scored an average of 4.4, which implies that users found the system intuitive. Behavioral Intention to Use (BI) scored 4.6, reflecting a strong likelihood of future use and recommendation among participants. Qualitative feedback reinforced these findings. Users described the AR visuals as immersive and noted that gaze and voice inputs felt natural and engaging. Overall, both functional results and user feedback support that MyGreenLens is a technically sound and educationally engaging application suitable for its intended audience. The functional testing process confirmed that all five core use cases (TC01–TC05) of the MyGreenLens application operated as intended. These tests included 3D object interaction, panel navigation, voice-triggered scene switching, and quiz logic. While some minor timing inconsistencies were observed, especially in high-light environments, they were corrected through refinements in object layer detection and MRTK configuration. No critical bugs were encountered during testing, and all essential features performed reliably. Following functional validation, a Technology Acceptance Model (TAM) questionnaire was distributed to 20 student participants who had tested the application. The questionnaire results yielded high scores across all three core constructs. The average score for Perceived Usefulness (PU) was 4.5, indicating that users found the AR experience highly beneficial for understanding environmental issues and 5R principles. The Perceived Ease of Use (PEOU) averaged 4.4, demonstrating that users found the interface intuitive and accessible. Behavioral Intention to Use (BI) scored the highest at 4.6, revealing strong willingness among participants to reuse and recommend the application. In addition to quantitative scores, user feedback revealed positive impressions of the immersive 3D visuals and natural interaction methods, especially gaze and voice input. The TAM-based assessment, combined with functional tests, supports the conclusion that MyGreenLens is not only operationally sound but also positively received by its intended audience.

Construct	**Code**	**Question**	**Average Score**
Perceived Usefulness (PU)	PU1	Does MyGreenLens enhance your awareness of plastic pollution?	4.43

	PU2	Does the app help you clearly understand the 5R principles?	4.5
	PU3	Does the app motivate you to adopt eco-friendly behavior?	4.71
	PU4	Are visuals and interactions effective in conveying information?	4.52
	PU5	Is the content relevant to real-life sustainability issues?	4.48
Average PU			4.53
Perceived Ease of Use (PEOU)	PEOU1	Is it easy to learn how to use MyGreenLens?	4.62
	PEOU2	Can you interact with the system without written instructions?	4.33
	PEOU3	Is switching scenes and using features straightforward?	4.57
Average PEOU			4.51
Behavioral Intention to Use (BI)	BI1	Would you use MyGreenLens again in the future?	4.48
	BI2	Would you recommend this application to others?	4.76
Average BI			4.62

Figure 3: Detailed TAM Mean Scores Table

Performance and User Testing Summary

Feature Tested	**Expected Result**	**Actual Result**	**Pass/Fail**
Voice command "go greenlens"	Scene switches to GreenLens	Works as expected	Pass
Shark tracks and hunts fish	Shark changes direction toward target	Smooth behavior	Pass
Whale animation	Natural tail and body	Realistic	Pass

	movement	animation	
Bubble particle system	Continuous vertical bubble stream	Displays properly	Pass
UI back button	Navigates to Mainmenu	Operates correctly	Pass

Figure 4: System Feature Testing Form

Category	**Score (1-5)**	**Feedback**
Immersion	5	Shark and whale movements felt natural.
Sound design	4	Whale calls enhanced the ocean atmosphere.
Scene switching	5	Intuitive and responsive via voice commands.
5R Content clarity	4	Educational material was clear and accessible.
Overall experience	5	Highly engaging and informative.

Figure 5: User Experience Feedback

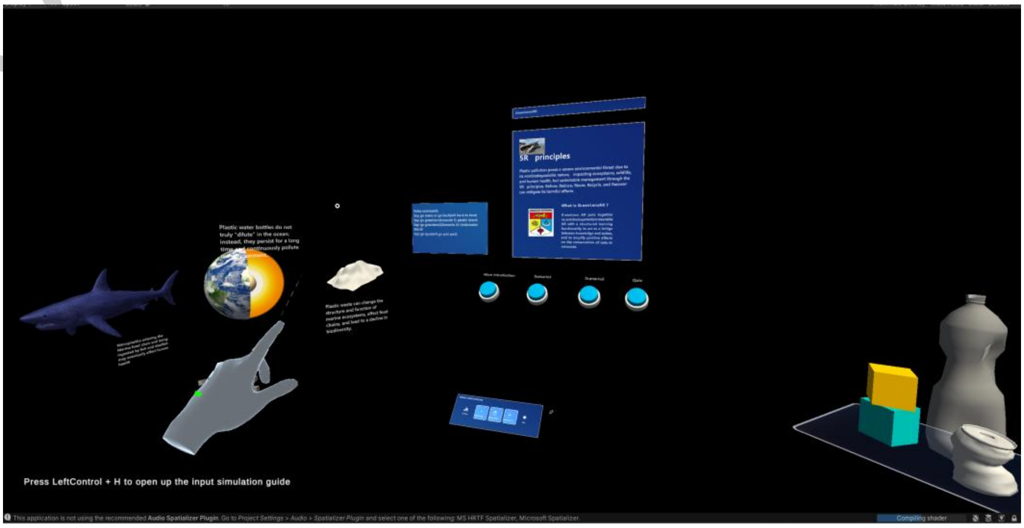


*Figure 6:*Main menu part

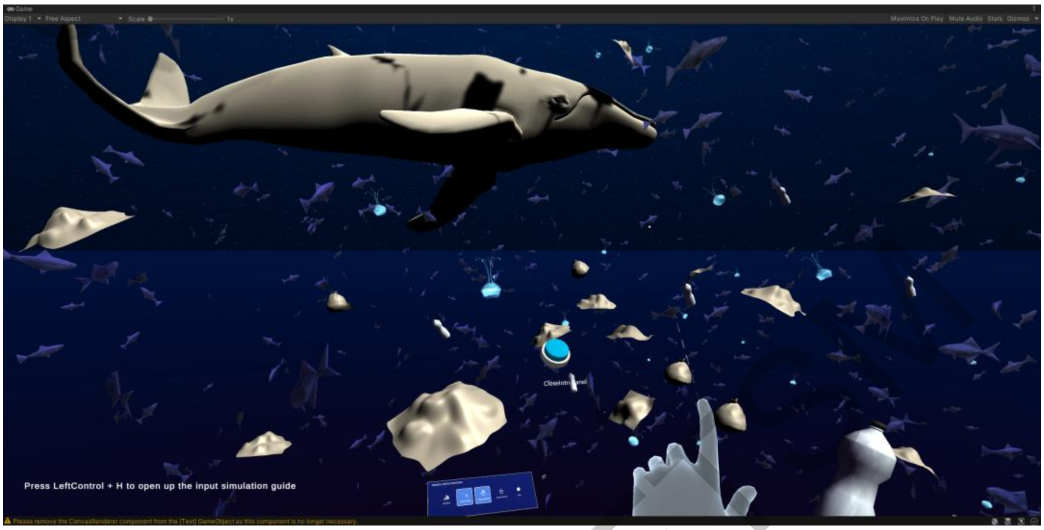


*Figure 7:*Scenario 1 under ocean

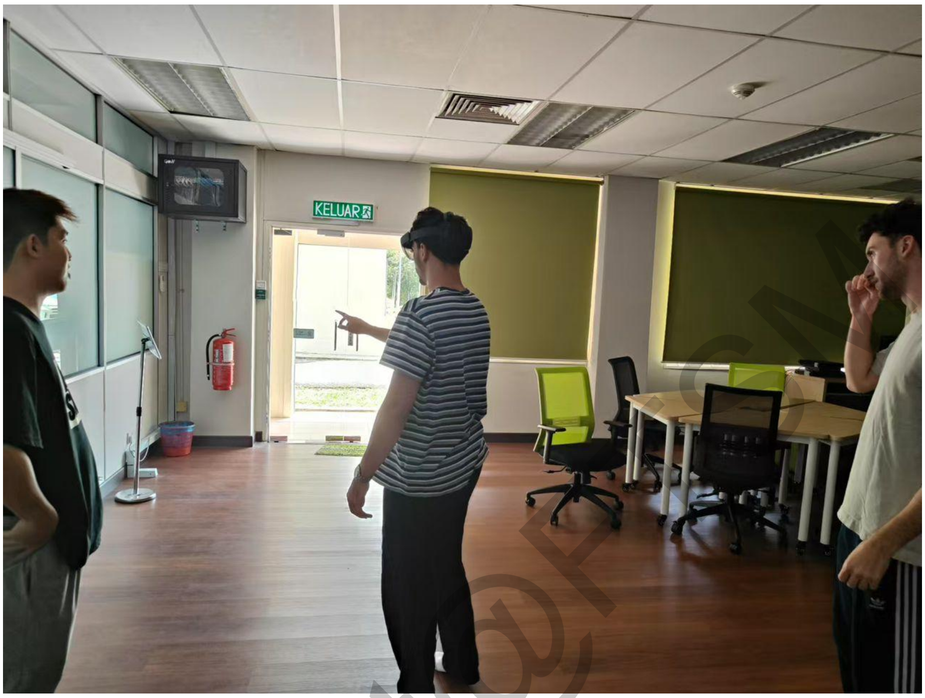
*Figure 8:*Scenario 2 beach

*Figure 9:*Quiz part

5.0 CONCLUSION

MyGreenLens was mass-scale and user-centric development of an AR-driven learning app to infuse green awareness. Using Microsoft HoloLens 2 and MRTK2, the site presented interactive learning experiences based on the 5R principles of sustainability—Refuse, Reduce, Reuse, 54 Repurpose, and Recycle. The site enabled users to interact with gaze, speech, and hand on a manual level in order to touch and control virtual scenes, objects, and ecological concepts by using smooth scene transfers and multimedia storytelling. The synergy between voice and manual buttons improved accessibility and provided a more inclusive interface. Quiz modules were also integrated to reinforce users' understanding of sustainability topics. Testing demonstrated the technical solidity and pedagogical suitability of the system. Each of the five main functions functioned as intended, and the system performed reliably in different test environments. While TAM-based evaluation confirmed high user acceptance of the system in terms of usefulness, ease of use, and behaviour intention, the long-term success of the project lies in its ability to deliver immersive learning in an intuitive, accessible, and educationally suitable format.

6.0 APPENDIX



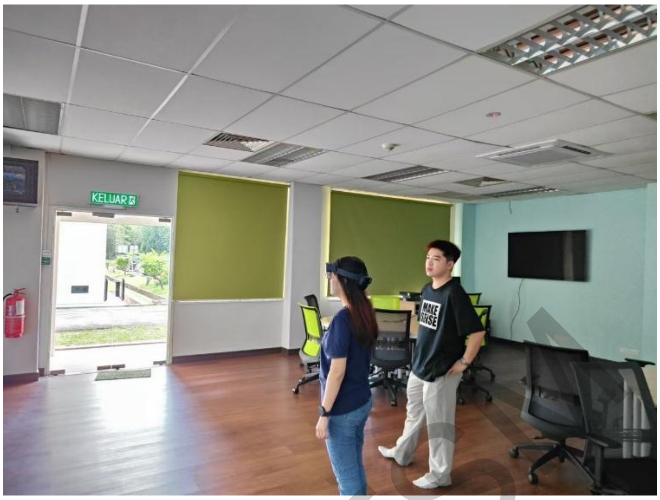


*Figure 10:*User testing photo

7.0 REFERENCES

Gope, L., & Mahato, P. (2024). *University student's perception towards augmented reality (AR). Transforming the Educational Landscape*, 195. Retrieved from https://www.researchgate.net/publication/

Di Mitri, M., Di Carmine, A., D'Antonio, S., & Capobianco, B. M. (2024). *Advancing pediatric surgery: The use of HoloLens 2 for 3D anatomical reconstructions in preoperative planning. Children, 12(1), 32*. Retrieved from https://www.mdpi.com/

Pantoja, F., & Bartsch, F. (2025). *Same same, but different: The strategic positioning of Apple Vision Pro and Meta Quest 3. SAGE Publications*. Retrieved from https://sk.sagepub.com/cases/skpromo/TCoKPL/same-same-different-strategic-positioning-apple-meta-quest-3

Ahmed, T., Lopez, J., & Rai, S. (2024). *Simulator sickness and performance in AR vs VR: A comparative analysis applied to additive manufacturing. Human Factors in Virtual and Augmented Reality*. Retrieved from https://openaccess.cms-conferences.org/publications/book/978-1-964867-35-9/article/978-1-964867-35-9_109

Vacirca, A., George, M., Wong, J., & Mesnard, T. (2024). *Intraoperative position system* *guided with augmented reality improves the learning curve of endovascular navigation in endovascular-naïve operators. Journal of Vascular Surgery.* Retrieved from https://www.sciencedirect.com/science/article/pii/S0741521424020317

Lürig, C., & Mentler, T. (2024). *Comparison of a kinematic and a dynamic docking task interaction technique in an interactive physics AR simulation. IEEE International Symposium on Mixed and Augmented Reality*. Retrieved from https://ieeexplore.ieee.org/abstract/document/10765261

Akilesh, S., John, S., Pai, T. V., & Sakthivel, V. (2024). *Extended reality as an assistive technology for patients suffering from neurodegenerative diseases. IEEE International Conference on Extended Reality Technologies*. Retrieved from https://ieeexplore.ieee.org/abstract/document/10823464

Hesselbein, C., Bory, P., & Canali, S. (2024). *Metaverse datafication: Technologies, definitions, and futures. Information, Communication & Society*. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/1369118X.2024.2443082

Lee, T. X., Tseng, Y. K., Tsai, W. P., Lin, W. K., & Zhou, S. K. (2024). *Advancing pure ray tracing for the simulation of volume holographic optical elements: Innovations in diffractive waveguide-based augmented reality systems. Optics Express,*32(25),45391.Retrieved:https://opg.optica.org/abstract.cfm?uri=oe-32-25-45391

Sibi, P. S., & Adithya, G. (2024). *Tourism entrepreneurship and the metaverse: Riding the new wave of the virtual revolution. Edward Elgar Publishing*. Retrieved from https://www.elgaronline.com/edcollchap/book/9781035328222/chapter11.xml

Gope, L., & Mahato, P. (2024). *University student's perception towards augmented reality (AR). Transforming the Educational Landscape*, 195. Retrieved from https://www.researchgate.net/publication/

Di Mitri, M., Di Carmine, A., D'Antonio, S., & Capobianco, B. M. (2024). *Advancing* *pediatric surgery: The use of HoloLens 2 for 3D anatomical reconstructions in preoperative planning*. *Children, 12*(1), 32. Retrieved from https://www.mdpi.com/

Pantoja, F., & Bartsch, F. (2025). *Same same, but different: The strategic positioning of Apple Vision Pro and Meta Quest 3*. *SAGE Publications*. Retrieved from https://sk.sagepub.com/cases/skpromo/TCoKPL/same-same-different-strategic-positioning-apple-meta-quest-3

Ahmed, T., Lopez, J., & Rai, S. (2024). *Simulator sickness and performance in AR vs VR: A comparative analysis applied to additive manufacturing*. *Human Factors in Virtual and Augmented Reality*. Retrieved from

https://openaccess.cms-conferences.org/publications/book/978-1-964867-35-9/article/978-1-964867-35-9_109

Vacirca, A., George, M., Wong, J., & Mesnard, T. (2024). *Intraoperative position system guided with augmented reality improves the learning curve of endovascular navigation in endovascular-naïve operators*. *Journal of Vascular Surgery*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0741521424020317

KOU BAOGUO (A197903)

Dr.Rimaniza Zainal Abidin

Faculty of Information Technology and Science

National University of Malaysia