JPPIPA 10(8) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Study on the Development of a Virtual Reality Application for Skeletal Anatomy Learning Using Rapid Application Development (RAD)

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Received: March 03, 2024
Revised: June 11, 2024
Accepted: August 25, 2024
Published: August 31, 2024

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DOI: 10.29303/jppipa.v10i8.8722

Abstract: The use of innovative multimedia technology continues to evolve and has now become a primary technology tool in education. Currently, the utilization of virtual reality (VR) technology is being used as an immersive medium for learning, especially in the field of medicine. Immersive technology is presented in 3D visualization, approaching real and relevant objects in medical education as an alternative to traditional teaching aids such as cadavers. In this research, an exploration of the VR environment was conducted in a case study of the skeletal system using 3D skull bone objects. The exploration involved tasks such as preparing the 3D skull bone object data assets in the 3D development environment, exporting data assets to the 3D-VR environment, and configuring aspects related to visualization and object control based on visual C#. So far, documentation of the 3D-VR application development environment and the trial results of the case study object development on the Unity platform have been produced. Additionally, documentation of the interface design application using Rapid Application Development (RAD) has also been generated. The Android-based VR application has functioned well in accommodating the skull object, designed with 3 layers of the skeletal system adjusted to their respective depths. The skull consists of 22 components, including *cranium*.

Keywords: Learning-VR; RAD model; Virtual Relaity; 3D *Skeletal System*;

Introduction

Developments in the scientific field (Purnama et al., 2024), technology, and information have become a significant direction in the increasing growth of technology (Wadjdi & Yuliza, 2023), including the development of educational software in medical education (Ginting et al., 2023). Digital technology and solutions play a crucial role in providing necessary healthcare services, especially in medical education and clinical care (Dhar et al., 2023). In this field, learning activities accompanied by simulations have become an increasingly important component. Simulation-based learning is believed to provide a conducive environment for medical students to practice their clinical skills and decision-making (Pottle, 2019). The presence of a conducive learning environment certainly allows for an effective learning process, leading to the achievement of desired learning outcomes (Moro et et al., 2017). So far, traditional learning methods are still used in teaching with cadaver materials and 2D atlases, according to Zargaran et al. (2020) and Chen et al. (2020). Although according to a survey Zargaran et al. (2020), conventional learning with cadavers remains the

How to Cite:
Wiriasto, G. W., Misbahuddin, Rachman, A. S., Harahap, I. L., Akbar, L. S. I., Iqbal, M. S., & Fikriansyah, M. (2024). Study on the Development of a Virtual Reality Application for Skeletal Anatomy Learning Using Rapid Application Development (RAD). *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5726–5733. https://doi.org/10.29303/jppipa.v10i8.8722

primary preference for students, this method still has limitations in providing theoretical information (Moro et al., 2017; Pottle, 2019), as well as ethical, financial, and substantial supervision concerns in its use.

The knowledge gap among medical professionals also underscores the need for technology that provides a comprehensive simulation database (Baniasadi et al., 2020). With the advancement of immersive virtual reality technology, the possibility of integrating this technology into the medical curriculum can significantly increase (Ekstrand et al., 2018; Labovitz & Hubbard, 2020). On the other hand, the development of digital multimedia technology innovations continues to grow and has been widely used as a primary technology tool in teaching. With the support of 3D environments and models (Nicholson et al., 2006) and network resources, virtual reality (VR) has evolved beyond the entertainment industry and entered the education sector (Syed et al., 2022). Every year, the number of internet users and various types of virtual reality (VR) shows consistent growth (Wadjdi & Yuliza, 2023).

Virtual Reality (VR) is a technology that allows users to experience a digitally constructed environment, which can mimic the real world or even environments that are impossible to access in real life and can be replicated (Ota et al., 1995; Stepan et al., 2017). In the field of medical education, VR has been used to provide a more interactive and immersive learning experience. VR Anatomy helps students' understanding by facilitating access to anatomical environments, providing assessment tools for students, and serving as a teaching aid for instructors (Falah et al., 2014). Medical education is a field that requires deep understanding and skills. However, conventional learning methods, such as studying from textbooks and videos, sometimes do not provide the expected experience in understanding complex and challenging topics. VR is considered more suitable in terms of user experience, usefulness, as a learning methodology, and for learning competency compared to other conventional delivery methods (Sattar et al., 2020). The potential use of VR has the potential to be used as an alternative educational and diagnostic tool that could improve conventional methods (Djukic et al., 2013).

With VR technology, medical students can experience more realistic simulations, engage in practice, and gain the necessary experience to deepen their understanding and skills, while also reducing the risk of mistakes when they are in the real world. VR can support anatomy teaching by complementing classrooms, books, and anatomy labs, and providing broader rotations for students across various teaching methods. This also helps avoid crowds around cadavers or VR devices (Duarte et al., 2020). VR has also proven to be a useful training tool akin to a virtual laboratory (Safiatuddin & Asnawi, 2023), which may succeed in cases where other initiatives fail to change behavior (Fertleman et al., 2018). The use of VR in medical education can help improve and enhance learning outcomes, allowing students to gain a maximum understanding and skill set (Huang et al., 2016). Additionally, the use of VR in medical education provides benefits for instructors in delivering complex and difficult-to-understand material.

VR has become a popular technique for providing more flexible and accessible medical simulation sessions that require less infrastructure. VR can enhance the effectiveness of medical education and facilitate better learning (Hamilton et al., 2021); however, its use is still limited, and more research is needed to develop effective VR materials. This technology has gradually been integrated into medical education programs (Gupta et al., 2023). The use of VR in teaching specific topics can help students learn and complete tasks more effectively (Timonen et al., 2022), tap into students' emotional core in new and exciting ways (Purnama et al., 2023), improve learning methodologies (Checa & Bustillo, 2020), and has shown to effectively improve student learning outcomes (Chen et al., 2020; Moro et al., 2017). The use of Virtual Reality (VR) and Augmented Reality (AR) in anatomy and physiology education, as well as in clinical medicine, can provide significant benefits (Agastya, 2024; Kim & Kim, 2023). In the study of nonlinear dynamics to form an effective learning model for medical students, the VR teaching model is expected to be a sensitive, stable, and efficient initial element (Gan et al., 2023). The improvement in VR model quality, alongside the enhanced ability of students to interact with virtual worlds (Sattar et al., 2020).

Method

The RAD (Rapid Application Development) model was used as a development phase for the skeletal system anatomy learning application, which is one of the methods in the Software Development Life Cycle (SDLC) (Gananjaya et al., 2022). This method supports system development with good flexibility.

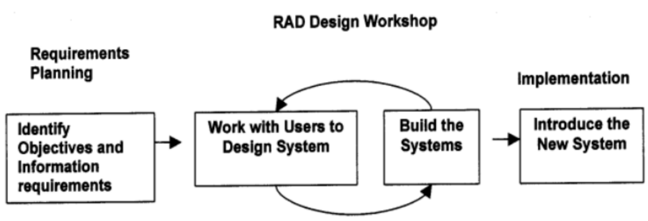


Figure 1. Model RAD (Sommerville, 2016)

In the RAD model shown in Figure 1, users (stakeholders) are also actively involved in the system development process. With this model, the RAD system development stages are based on agile methods (Sommerville, 2016).

Table 1. Details of the RAD Process in the Ongoing Research

Process	Step	Detail
Requirements Planing	- Requirement Engineering (RE)	In this stage, interviews are conducted between researchers, medical experts, and users.
	User and expert interviews covering:	Data collection is carried out, including charts, object data, system application workflow descriptions, and a list of terms.
	System features	Collection of tools and materials used in the system development is also performed.
RAD Design Workshop	System Design - Gameplay design - UI/UX design	In this stage, system design is developed, resulting in an output such as a UML diagram.
	System development - Coding - Testing - Debugging	This stage also involves creating a prototype based on the design.
Implementation	System testing	In this stage, testing is conducted to assess the application's feasibility using the black box testing method.
	Release	At this stage, the system version is ready for user use.

Requirement Planning Stage: Requirement Engineering**:** In this stage, information and data regarding the research objects are collected.

(a) (b)

Figure 2. (a) Learning activities using a preparate as an alternative to cadavers; (b) The teaching doctor demonstrates the skeletal system using references from Sobotta and Grant's 2D anatomy atlas *(source: Medical Education Program - University of Mataram)*

The research team, along with the Medical Education department at Universitas Mataram, demonstrates the teaching aids used in learning. Figure 2 shows the teaching aid called a preparate, used as an alternative to cadavers. This led to the design of VR materials where digitization of real cadaver objects into 3D visualization is necessary.

Requirement Planning Stage: Data Preparation for 3D Asset: To assess the complexity of developing the entire system, at this stage, the materials (3D data assets) related to the learning content need to be created and prepared. This involves manually digitizing or transforming bone objects into 3D form (Harahap et al., 2023).

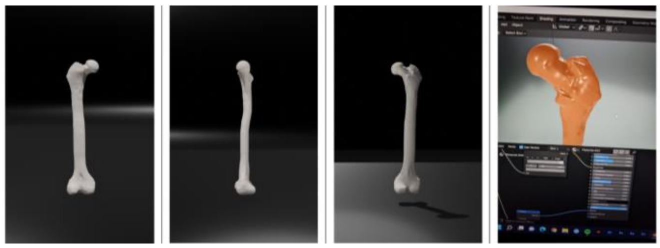


Figure 3. Dataset transformation from image 2D to 3D model

Figures 3(a, b, c) show the visual transformation of the object from two-dimensional (2D) to three-dimensional (3D) using Blender software tools. This transformation is essential as primary data in the construction of object materials for VR devices. Figure 5(d) displays the visual of the 3D femur bone object (Harahap et al., 2023).

Requirement Planning Stage: Complete 3D Skeletal System Data Asset; Figure 4 represents the 3D skeletal system data asset used in this study as the primary material for developing the medical learning application.

This data asset is open-source (Z-Anatomy, 2022), allowing researchers to use it in various VR application developments. The Blender application environment for 3D visual development is shown.

Requirement Planning Stage: Analysis of hardware and software needs. The software required for developing this learning application includes: meta-oculus 2 VR headset with controller; windows 11 OS; Minimum hardware specifications: VGA Graphics 8 GB, RAM 32 GB; blender 3D environment with 3D skeletal system asset (Z-Anatomy, 2022) and Unity 3D Engine.

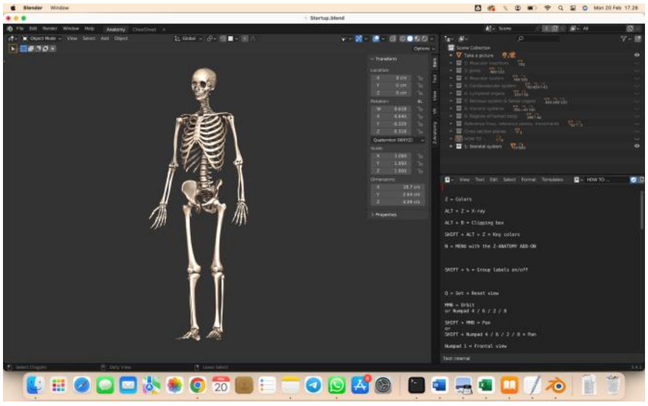


Figure 4. 3D skeletal system dataset object in *blender* application

Result and Discussion

Application Design: Gameplay, User Interface, and User Experience Design; In the design of this learning application, users can interact by controlling visualization objects with the following functionalities: Rotation: Rotating the object 360 degrees; Zoom: Zooming in to enlarge and zooming out to reduce the size of the object; Grab: Moving and separating objects, holding or detaching parts of the human skeleton; and Observe**:** Viewing detailed explanations of specific parts of the human skeleton Figure 5.

In the application design, the visual object of the skeletal skull system can be rotated by holding the '*X*' button on the Secondary VR controller and swinging the controller in the desired direction of rotation. The main gameplay will focus on matching part names by grabbing the name of a part and placing it into an empty box that points to a specific part of the bone. Enlarging the human skeleton object can be done by holding both grip buttons on each controller and moving the controllers apart to zoom in, or bringing the controllers closer together to zoom out.

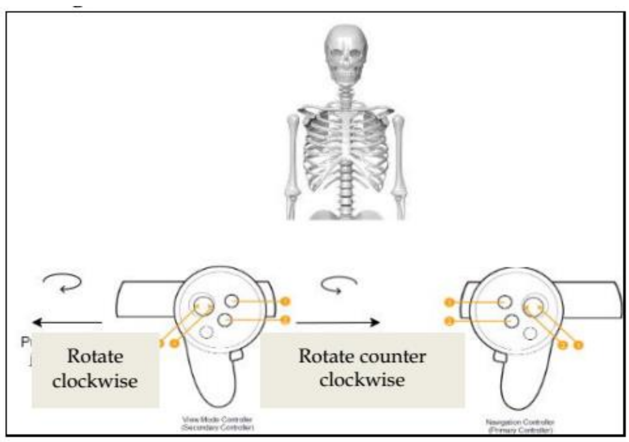
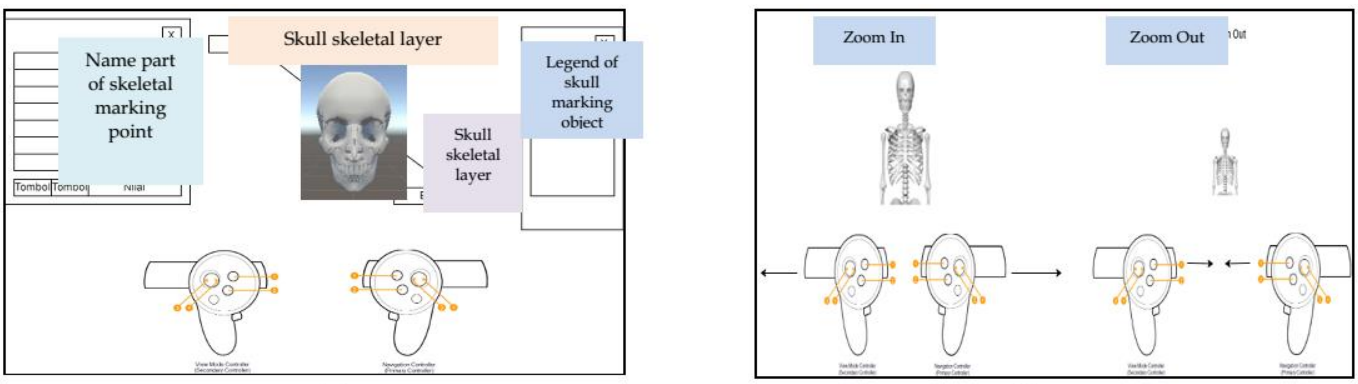


Figure 5. Rotate design view

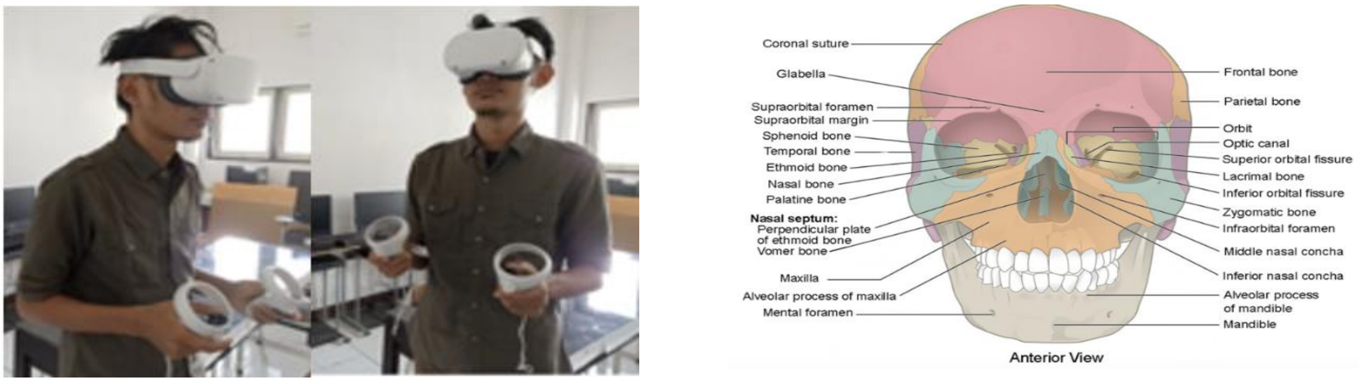
In the Unity project workspace design, there is a scene with several objects visible in the left window. By default, when creating a new project, it will generate 2 objects: the *main camera*, which serves as the user's viewpoint, and the *directional light*, which controls the lighting for the entire scene.



(a) (b)

Figure 6. Gameplay design UI/UX: (a) Observe, scaling and grab design view; (b) Zooming design view

A puzzle game model has been designed to facilitate deeper interaction, where users learn by matching medical Latin names or terms with marked object markers. Implementation in the VR Environment: Data assets within the Unity VR development environment. A trial was conducted to create a new project in the 3D modeler environment using Unity, with the aim of displaying bone objects in the Unity workspace and rendering them on the VR camera.



(a) (b)

Figure 7. (a) Simulation of running the VR device and hand controllers; (b) Skull cranium in the workspace in Unity 3D after the data asset object has been successfully imported (Anonym, 2019)

In the trial within the unity environment, the data asset object used as a sample for the entire skeletal system is the skull. The bone object data files are exported into the format *filename.fbx* using *blender* 3D development tools. After exporting the file format, the object is saved into a newly created Unity project and then imported into the main screen or scene, as shown in Figure 7. The next testing phase involves adding data or information in the form of '*name*' labels marking on several bone parts using the *tooltip* menu, as seen in Figures 8 and 9.

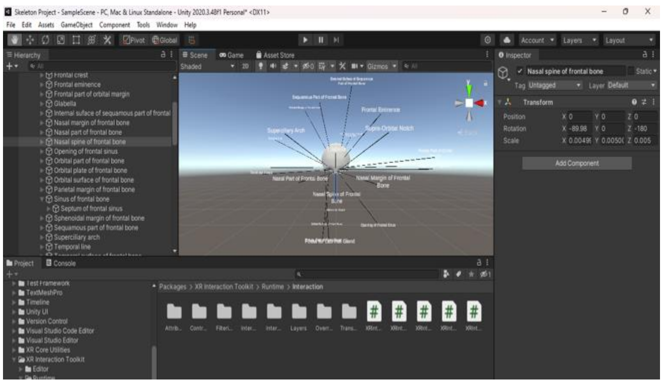


Figure 8. 3D unity workspace after added *tooltip* in the object *marking*

In Figure 8, it can be seen that labels for the parts of the front of the skull, or frontal bone, have been added. After adding colliders and *rigidbodies* to the bone objects, these objects are now eligible for physical interaction with the user using the VR controller. This week, a feature was added to move bone objects using the left VR controller. To move an object in Unity VR, two important components are required: the component that acts as the interactor (the object that performs the interaction) and the component that acts as the interactable (the object that receives or responds to the interaction from the interactor). For the interactor, the *XR Ray Interactor* component will be used on the left VR controller. With the *XR Ray Interactor*, the controller can interact with interactable objects from a distance using a raycast or detection line. When the scene is run, it will appear as shown in Figure 9.

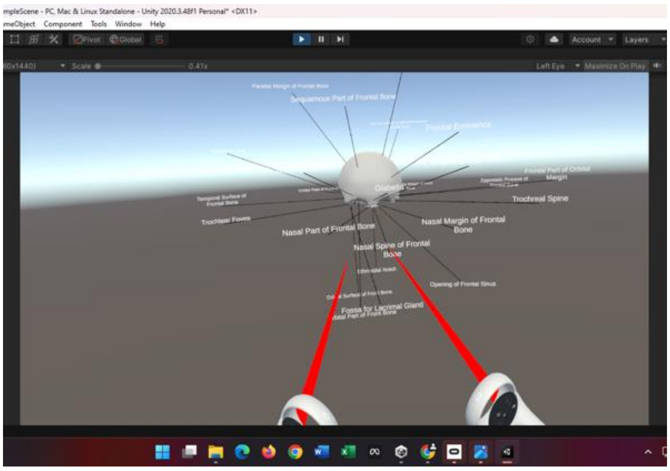


Figure 9. Scene view from apps running after added unity *tooltip* into object

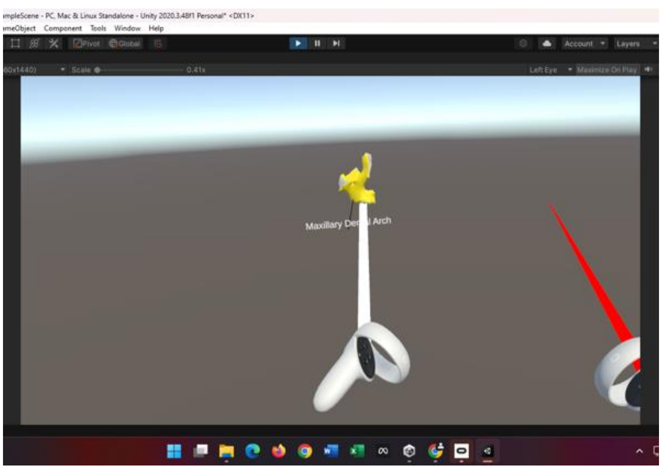


Figure 10. Scene view from apps running after added unity *hover* into object

Additionally, for another part of the bone, the hover feature has also been tested, as shown in Figure 10. The function of this feature is that when the controller's line is directed at a part of the skull, specifically the left *maxilla* bone, the color of that bone changes to yellow. Once the line moves away from the bone area, the color returns to its original state. On the left controller device, the *XR Direct Interactor* component has also been added, which enables the controller to interact with physically touchable interactable objects through the controller's *collider*.

Conclusion

In conclusion, a skeletal system learning application has been developed with a focus on the skull object, using the Rapid Application Development (RAD) software development method. This application allows user interactions such as *rotation, zoom, scaling*, and object manipulation. Testing has been conducted in a 3D-VR development environment, and the results from trials in the Unity workspace have shown success. The Android-based VR application *.apk** has functioned well, accommodating a skull object designed with 3 layers of skeletal system depth. The skull itself consists of 22 main parts, which protect the brain and form the facial structure.

Acknowledgments

The author would like to thank all parties involved in this research: Thank you for the discussion with Dr. Owais Ahmed Malik from the University of Brunei Darussalam.

Author Contributions

G.W.W, M, I.L.H, M.F: Preparation of the first draft, results, discussion, methodology, conclusion, review, and editing; A.S.R, M.S.I, L.A.S.I.A: Analysis and proofreading;

Funding

This research was funded by the University of Mataram with PNBP Ass.Prof. Grant 2023.

Conflicts of interest

The authors declare no conflict of interest.

References

Agastya, I. G. E. A. A. (2024). Penggunaan Virtual Reality Dan Augmented Reality Dalam Pendidikan Kedokteran. *National Conference on Applied Business, Education, & Technology (NCABET)*, *3*(1), 806–815. https://doi.org/10.46306/ncabet.v3i1.171

Anonym. (2019). *Cranium Anterior View*. Retrieved from https://courses.lumenlearning.com/suny-ap1/chapter/the-skull/

Baniasadi, T., Ayyoubzadeh, S. M., & Mohammadzadeh, N. (2020). Challenges and Practical Considerations in Applying Virtual Reality in Medical Education and Treatment. *Oman Medical Journal*, *35*(3), 125–125. https://doi.org/10.5001/omj.2020.43

Checa, D., & Bustillo, A. (2020). A review of immersive virtual reality serious games to enhance learning and training. *Multimed Tools Appl*, *79*, 5501–5527. https://doi.org/10.1007/s11042-019-08348-9

Chen, S., Zhu, J., Cheng, C. C., Pan, Z., Liu, L., Du, J., Shen, X., Shen, Z., Zhu, H., Liu, J., Yang, H., Ma, C., & Pan, H. (2020). Can virtual reality improve traditional anatomy education programmes? A mixed-methods study on the use of a 3D skull model. *BMC Medical Education*, *20*. https://doi.org/10.1186/s12909-020-02255-6

Dhar, E., Upadhyay, U., Huang, Y., Uddin, M., Manias, G., Kyriazis, D., Wajid, U., AlShawaf, H., & Syed Abdul, S. (2023). A scoping review to assess the effects of virtual reality in medical education and clinical care. *Digital Health*, *9*. https://doi.org/10.1177/20552076231158022

Djukic, T., Mandic, V., & Filipovic, N. (2013). Virtual reality aided visualization of fluid flow simulations with application in medical education and diagnostics. *Computers in Biology and Medicine*, *43*(12), 2046–2052. https://doi.org/10.1016/j.compbiomed.2013.10.004

Duarte, M. L., Santos, L. R., Guimarães Júnior, J. B., & Peccin, M. S. (2020). Learning anatomy by virtual reality and augmented reality A scope review. *Morphologie*, *104*(347), 254–266. https://doi.org/10.1016/j.morpho.2020.08.004

Ekstrand, C., Jamal, A., Nguyen, R., Kudryk, A., Mann, J., & Mendez, I. (2018). Immersive and interactive virtual reality to improve learning and retention of neuroanatomy in medical students: A randomized controlled study. *CMAJ Open*, *6*(1), 103– 109. https://doi.org/10.9778/cmajo.20170110

Falah, J., Khan, S., Alfalah, T., Alfalah, S. F. M., Chan, W., Harrison, D. K., & Charissis, V. (2014). Virtual Reality medical training system for anatomy education. *2014 Science and Information Conference*, 752–758. https://doi.org/10.1109/SAI.2014.6918271

Fertleman, C., Aubugeau-Williams, P., Sher, C., Lim, A.-N., Lumley, S., Delacroix, S., & Pan, X. (2018). A Discussion of Virtual Reality As a New Tool for Training Healthcare Professionals. *Frontiers in Public Health*, *6*, 44. https://doi.org/10.3389/fpubh.2018.00044

Gan, W., Mok, T.-N., Chen, J., She, G., Zha, Z., Wang, H., Li, H., Li, J., & Zheng, X. (2023). Researching the application of virtual reality in medical education: One-year follow-up of a randomized trial. *BMC*

Medical Education, *23*(1), 3. https://doi.org/10.1186/s12909-022-03992-6

Gananjaya, I. J. O. T. C., Christanto, J. F. A., Widianto, M. H., & Audrey, J. (2022). Lone Burglar Stealth Game Development Using Rapid Application Development. *2022 4th International Conference on Cybernetics and Intelligent System (ICORIS), Prapat, Indonesia*, 1–5,. https://doi.org/10.1109/ICORIS56080.2022.10031499

Ginting, F. W., Sakdiah, H., Widya, & Unaida, R. (2023). Analysis of the Need for Development of Virtual Reality-Based Learning Media to Build Technological Pedagogical and Content Knowledge (TPACK) Competencies for Prospective Physics Teachers. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 12098–12103. https://doi.org/10.29303/jppipa.v9i12.6163

Gupta, S., Wilcocks, K., Matava, C., Wiegelmann, J., Kaustov, L., & Alam, F. (2023). Creating a Successful Virtual Reality-Based Medical Simulation Environment: Tutorial. *JMIR Medical Education*, *9*, 41090. https://doi.org/10.2196/41090

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1–32. https://doi.org/10.1007/s40692-020-00169-2

Harahap, I. L., Syamsun, A., Herlina, L., & Wiriasto, G. W. (2023). Development of Virtual Reality for Forensic Anthropology. *Jurnal Kedokteran*, *12*(3), 298–300. https://doi.org/10.29303/jku.v12i3.960

Huang, H.-M., Liaw, S.-S., & Lai, C.-M. (2016). Exploring learner acceptance of the use of virtual reality in medical education: A case study of desktop and projection-based display systems. *Interactive Learning Environments*, *24*(1), 3–19. https://doi.org/10.1080/10494820.2013.817436

Kim, H.-Y., & Kim, E.-Y. (2023). Effects of Medical Education Program Using Virtual Reality: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health*, *20*(5), 3895. https://doi.org/10.3390/ijerph20053895

Labovitz, J., & Hubbard, C. (2020). The Use of Virtual Reality in Podiatric Medical Education. *Clinics in Podiatric Medicine and Surgery*, *37*(2), 409–420. https://doi.org/10.1016/j.cpm.2019.12.008

Moro, C., Štromberga, Z., Raikos, A., & Stirling, A. (2017). The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *American Association of Anatomists*, *10*, 549–559. https://doi.org/10.1002/ase.1696

Moro, C., Štromberga, Z., & Stirling, A. (2017). Virtualisation devices for student learning: Comparison between desktop-based (Oculus Rift) and mobile-based (Gear VR) virtual reality in medical and health science education. *Australasian Journal of Educational Technology*, *33*(6). https://doi.org/10.14742/ajet.3840

Nicholson, D. T., Chalk, C., Funnell, W. R. J., & Daniel, S. J. (2006). Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model. *Medical Education*, *40*(11), 1081–1087. https://doi.org/10.1111/j.1365-2929.2006.02611.x

Ota, D., Loftin, B., Saito, T., Lea, R., & Keller, J. (1995). Virtual reality in surgical education. *Computers in Biology and Medicine*, *25*(2), 127–137. https://doi.org/10.1016/0010-4825(94)00009-F

Pottle, J. (2019). Virtual reality and the transformation of medical education. *Future Healthcare Journal*, *6*(3), 181–185. https://doi.org/10.7861/fhj.2019-0036

Purnama, I., Menrisal, P., W., N., S, M., & P, R. R. (2023). Virtual Reality for Future Education: Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 322–327. https://doi.org/10.29303/jppipa.v9i7.4485

Purnama, I., Prananta, A. W., & Wijanarko, T. (2024). Recent Trends in Virtual Reality for Meaningful and Fun Science Learning: A Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 207–213. https://doi.org/10.29303/jppipa.v10i5.7159

Safiatuddin, S., & Asnawi, R. (2023). Effectiveness of Using Virtual Reality-Based Virtual Laboratories in the Internet of Things Course. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 5062–5070. https://doi.org/10.29303/jppipa.v9i7.4040

Sattar, M. U., Palaniappan, S., Lokman, A., Shah, N., Khalid, U., & Hasan, R. (2020). Motivating Medical Students Using Virtual Reality Based Education. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(02), 160. https://doi.org/10.3991/ijet.v15i02.11394

Sommerville, I. (2016). *Software engineering* (10th ed.). Addison Wesley Longman Publishing Co., Inc. Retrieved from https://software-engineering-book.com/

Stepan, K., Zeiger, J., Hanchuk, S., Del Signore, A., Shrivastava, R., Govindaraj, S., & Iloreta, A. (2017). Immersive virtual reality as a teaching tool for neuroanatomy. *International Forum of Allergy & Rhinology*, *7*(10), 1006–1013. https://doi.org/10.1002/alr.21986

Syed, A. S., Upadhyay, U., Salcedo, D., & Lin, C.-W. (2022). Virtual reality enhancing medical education and practice: Brief communication. *Digital Health*, *8*, 205520762211439. https://doi.org/10.1177/20552076221143948

Timonen, T., Dietz, A., & Linder, P. (2022). The effect of virtual reality on temporal bone anatomy evaluation and performance. *Eur Arch Otorhinolaryngol*, *279*. https://doi.org/10.1007/s00405-021-07183-9

Wadjdi, F., & Yuliza, Y. (2023). The Augmented and Virtual Reality in HRM Development. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1137–1141. https://doi.org/10.29303/jppipa.v9i11.5333

Z-Anatomy, A. (2022). *An opensource 3D Anatomy*. Retrieved from https://www.z-anatomy.com/

Zargaran, A., Turki, M. A., Bhaskar, J., Spiers, H. V. M., & Zargaran, D. (2020). The Role of Technology in Anatomy Teaching: Striking the Right Balance. *Advances in Medical Education and Practice*, *11*, 259–266. https://doi.org/10.2147/AMEP.S240150