Received: 1 February 2023; Revised: 5 March 2023; Accepted: 1 April 2023; Published: 1 June 2023

Design and Development of a Virtual Reality Anatomy Medical Classroom by Utilizing Cognitive Load Theory and The Virtual Medical Technology Acceptance Model (VMedTAAM)

Muhammad Aminuddin Akmal Mohd Hamizi, Nur Azlina Mohamed Mukmin*, Ummie Haniffah Ariffin

[1]*Centre for Instructional Technology & Multimedia, Universiti Sains Malaysia, Malaysia;*
aminmizi@student.usm.my, nurazlina@usm.my, ummie.haniffah@student.usm.my

**corresponding author*

Abstract

Without a doubt, medical sciences have a significant effect on our lives. The medical sciences aid in the diagnosis and treatment of diseases and ailments. According to studies, the majority of students utilised conventional instructional methods in their practical classroom. Virtual reality is one of the immersive technologies that aid the learning process by reducing cognitive load. According to Mayer's 12 Multimedia Principles, the learning process is enhanced when multimedia elements such as visuals and audio are combined. This study presented the design and development of a VR anatomy medical classroom by employing cognitive load theory and determining the acceptability of virtual reality technology for the medical sciences. The combination of the ADDIE model and 12 Mayer's Principle of Multimedia improved the learning method and research framework for the use of VR-based technologies in medical sciences education. Utilizing a modified version of the Technology Acceptance Model (TAM), the VMedTAAM is used to determine the acceptance of technology in medical education. The result will serve as a guide for future VR developers to improve the design of immersive technology in this area.

Keywords: CTL, technology acceptance model, VR anatomy, cognitive load, medical sciences.

INTRODUCTION

Virtual reality (VR) is one of the most well-known and rapidly expanding technologies that offers enormous opportunities in numerous fields, including education, medical health, and sports. VR provides a superior three-dimensional (3D) learning visualization than other technologies, such as audio-based and video-based learning. Also included is human-machine interaction, which has been shown to improve learning methods, especially in the medical field. This tool allows instructors and students to have a more realistic experience in the virtual worlds they explore. The utilization of VR as a learning tool increases motivation among students, as stated by (Sattar et al., 2019).

According to the standard model of training facilities, not only is there a high price tag for the training itself, but there are also high costs associated with the trainers' time and travel, the upkeep of the physical space, and the training itself (Sattar et al., 2019). However, virtual reality is convenient because it cuts down on time and money spent on travel and doesn't require any special training or knowledge to operate. Challenges exist in the design and development of VR with appropriate techniques and materials for use in the medical sciences. Furthermore, the instructional design must be considered to ensure that students understand the VR tasks that must be completed. According to Shen and Lai (2018), instructional design is the methodical process of planning, creating, testing, and managing all teaching parts to ensure students learn.

In addition, when designing a VR anatomy classroom, students' working memory must be considered. This is due to the fact that the more information loaded into working memory, the lower the learning efficiency (Shirley, 2022). Furthermore, some students may need more time to process the theory they learned in class when using the traditional method of learning it, which involves slides and video presentations with a lot of words and information that needs to be processed. Zhang et al. (2021) agree that using virtual technology in the classroom helps students better understand concepts that are difficult to describe with words alone.

A major hurdle to the widespread implementation of VR in educational settings, particularly in the medical sciences, is the level of acceptance of such technology among both students and educators. This is due to the fact that the application of VR technology in the healthcare industry is still in its infancy (Kassutto et al., 2021). For that reason, it is important to create an engaging and effective VR for medical sciences education in order to alter the perspectives of both students and teachers. Thus, the framework of the Technology Acceptance Model by Davis (1989) is adapted to form the Virtual Medical Technology Acceptance Anatomy Model (VMedTAAM).

The following section will discuss related studies from prior research, such as virtual reality, cognitive load, instructional design, and technology acceptance.

OVERVIEW OF THE STUDY

Virtual Reality in Medical Education

The use of digital gadgets in learning and education is quickly expanding (Zawacki-Richter & Latchem, 2018). Several technologies, including augmented reality (AR), virtual reality (VR), mixed reality (MR), and extended reality (XR), are used in the field of education (Radianti et al., 2020). However, according to Hsieh & Lee (2018), the usage of VR and AR in medical education has steadily

Received: 1 February 2023; Revised: 5 March 2023; Accepted: 1 April 2023; Published: 1 June 2023

increased thanks to applications like VR exposure therapy, VR anatomy, and AR autism treatment. Additionally, the utilization of immersive technology, particularly VR, may raise trainees' competence levels to 95% (Samadbeik et al., 2018). Nonetheless, there are a number of instructional design factors that must be taken into consideration in order to develop an effective instructional tool for this VR anatomy classroom.

Meanwhile, VR is an immersive technology that creates an interactive 3D virtual environment Suh & Prophet (2018) and allows users to become fully immersed in a manufactured environment through dynamic engagement with the content (Nurul et al., 2019). Additionally, the "3I" design of virtual reality is built on the three pillars of immersion, imagination, and interaction (Qingtao, 2020). These three aspects of VR could raise attention (Zhao et al, 2020) and enhance instructional techniques (Hsieh & Lee, 2018). Despite this, it appears that the use of immersive technology, particularly in virtual reality, is still in its early stages, as indicated by earlier research by Kassutto et al (2021) and Lin et al. (2022). Thus, this study tends to fill in any gaps in the application of VR for medical education specifically in the anatomy classroom.

Working Memory and Cognitive Load Theory

It is essential to concentrate on working memory in order to maximize the efficiency of the learning strategy (Vesga et al., 2021). Working memory is a finite computational resource used for storing and processing information simultaneously in one's brain (Anmarkrud et al., 2019). It is also essential in cognitive load theory (CLT) due to its interconnectedness (Anmarkrud et al., 2019). Information is more difficult to concentrate on, practice, and recall material when the brain is under a lot of cognitive load (CL) or cognitive burden (Shirley, 2022). However, to improve the effectiveness of the learning process, there are three subscales of cognitive load that require attention. The three subscales of CL, according to Sweller et al (2019), are the intrinsic load (IL), extraneous load (EL), and germane load (GL).

Intrinsic load is the term for the mental strain encountered when completing a learning assignment. It depends on how challenging the task is and how effectively it integrates with other elements (Mutlu-Bayraktar et al., 2019). The learner's knowledge determines the degree of intrinsic load (Anmarkrud et al., 2019). Hence, the intrinsic cognitive load does not just depend on the learners' prior knowledge, it also depends on the instructional design and how the materials are presented. While the learner's prior knowledge is undoubtedly a factor in effective IL, an instructional design strategy that is more specifically focused is necessary for effective information presentation. This is because a superb instructional design will lead to a great and wonderful product (Budoya et al., 2019).

One of the three components of CLT that can be influenced by the instructional approach is extraneous load (Albus et al., 2021; Mutlu-Bayraktar et al., 2019). EL occurs when an unnecessary learning process directly contributes to learning (White & Candidate, 2018). Text instructions on the task to be accomplished, the use of unnecessary graphics as decorations for the virtual classroom, and the learning session's erratic flow are examples of excess load, particularly in VR. Based on the preceding instances, it will result in a larger working memory to analyze, store, and manipulate information simultaneously. Therefore, the reduction of unnecessary elements in sequence tasks is needed for an efficient instructional design for this VR anatomy classroom (White & Candidate, 2018).

Furthermore, the germane load is a strain that appears while managing and building mental structures (Mutlu-Bayraktar et al., 2019). Since it results from student exertion, it is a type of "good" load that has consequences for students' progress (Albus et al., 2021). The influence of an immersive environment could make using VR more motivating Kavanagh et al (2017) to accomplish the task. By bridging the gap between instructional information and student motivation, VR has the potential to improve medical education. In other words, if students feel more motivated, they will exert more effort to complete more assignments. These findings lead to the conclusion that apps with lower EL and IL and higher GL lighten the cognitive load and improve learning efficiency.

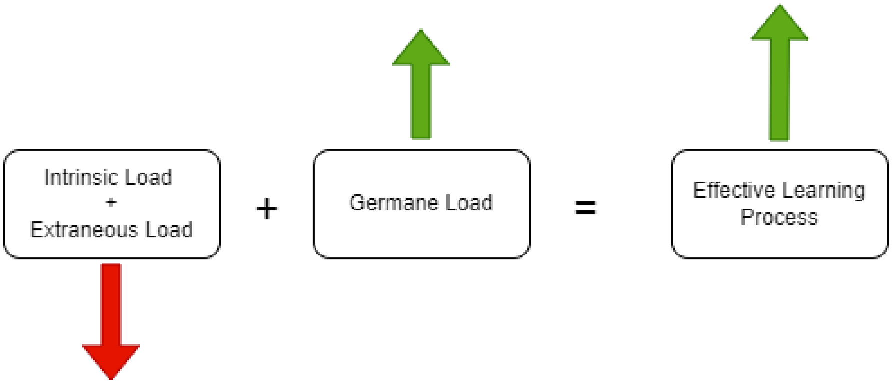

Figure 1: The illustration of the relationship between IL, EL, and GL and the effectiveness of the learning process

Instructional Design and Mayer's 12 Principles of Multimedia

It will be essential to use a combination of a high-quality instructional design model, a multimedia framework guideline, and cognitive load in order to achieve the objective of minimizing cognitive load in this application. The ADDIE paradigm is used for educational purposes in VR development the majority of the time (77.42%) (Hamizi et al., 2022). Furthermore, according to Basu (2018), one sort of instructional design that employs a systematic and iterative approach to guide developers in a way that allows them to be both adaptable and innovative is the ADDIE model. Nonetheless, since Virtual Reality features include multimedia components such as 3D, audio, video, and still images Kassutto et al (2021), Mayer's 12 Principles of Multimedia should be incorporated into the construction of VR to ensure maximum effectiveness.

Received: 1 February 2023; Revised: 5 March 2023; Accepted: 1 April 2023; Published: 1 June 2023

Despite this, the ADDIE model consists of five development processes, which are analysis of the problem and needs, design of activities and materials, development of the objective goals, implementation of training, and evaluation of the instruction and outcomes (Hamizi et al., 2022). Moreover, a thorough examination of the difficulties and needs influences a great outcome. In this analysis phase, several elements need to be taken into consideration such as targeted audiences, characteristics of the targeted audiences Aldoobie (2015), appropriate software to be utilized, and the supported hardware to use for the development of the application. In addition, designing learning objectives and using a proper framework are among the other tasks that need to be completed during the design process. The following step in developing performance aids is to incorporate content into the layout (May, 2018). The application is then made available to the intended audiences, and during the implementation and evaluation phases, the responses of the audiences are used to gauge the application's acceptance.

According to the previous studies, Mayer's 12 Principles of Multimedia was applied in digital presentation (Nurul Fadly et al., 2022), lowering CL in general (Ginns & Leppink, 2019) and enhancing biology lectures using VR (Parong & Mayer, 2018). Studies examining the application of Mayer's 12 Principles of Multimedia in medical education are still lacking. However, Lauren (2021) revised the list of Mayer's 12 Principles which aids in the selection of the appropriate principles for application in this study. The Coherence Principle (CP) is applied by keeping the content basic and understandable in order to create a VR anatomy classroom by avoiding unnecessary load. The Spatial Contiguity Principle (SCP) was also utilised in this application through direct instruction, which involve putting together the related words and pictures. Additionally, Segmenting Principles (SP) helps assist students by segmenting the content to increase their comprehension. Thus, these three principles are suited to use in the development of VR anatomy classrooms.

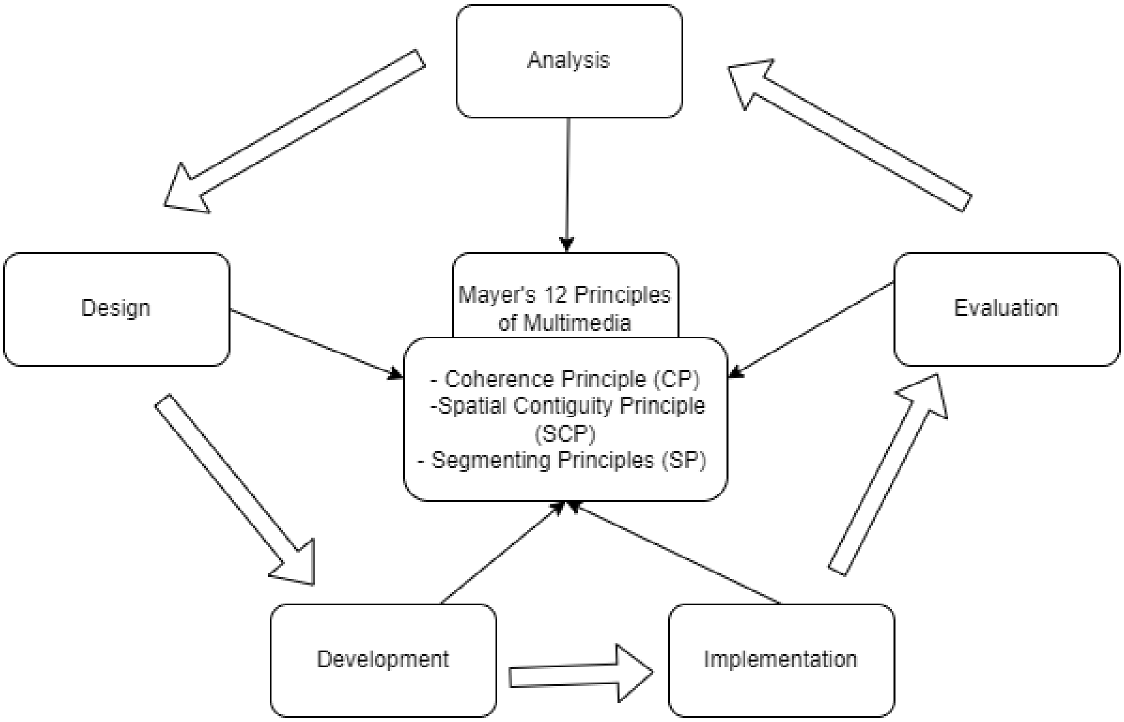

Figure 2: The implementation of Mayer's 12 Principles of Multimedia in the ADDIE model

Technology Acceptance Model

Technology acceptance is one of the important factors in predicting the level of acceptance of the audiences. The Technology Acceptance Model (TAM) by Davis (1989) is one of the most popular models used to forecast the acceptance of technology. TAM is made up of four basic components which are (i) perceived usefulness, (ii) perceived ease of use, (iii) behavioural intention use, and (iv) actual system use. Early researchers have tweaked and altered TAM. Chau and Hu (2001) altered TAM in 1996 by eliminating attitude because it doesn't seem to fully mediate the effect of perceived usefulness and perceived ease of use on behavioural intention.

Surendran (2013) also discovered that Agarwal and Prasad in 1998, modified TAM by incorporating the idea of compatibility. Ching & Roberts (2020) rearranged the timeline of TAM's changes and discovered that Venkatesh & Davis' 1996 simplification of TAM by including just five factors (i) external variables; The five factors which are: (i) the extent of the effect, (ii) the perceived usefulness, (iii) the perceived ease of use, (iv) the behavioural intention, and (v) the usage behaviour.

However, the original TAM criteria which are perceived usefulness (PU) and ease of use (EOU) will be adapted in this application. This study also eliminates another element by substituting with personal

Received: 1 February 2023; Revised: 5 March 2023; Accepted: 1 April 2023; Published: 1 June 2023

intrinsic capability, intention to use, context, and trust of use to produce the Virtual Medical Technology Acceptance Anatomy Model (VMedTAAM).

According to the VMedTAAM model depicted in Figure 3, technology acceptance will be measured based on the extent to which students enjoy the context of the VR anatomy classroom, which is related to their intrinsic capability (PIC) and is dependent on their confidence in using VR technology to operate the immersive anatomy classroom in another virtual world. Students' confidence in their ability to finish assignments and interest in the classroom's topic and materials make up the perceived usefulness (PU). The PIC method leaves behind students who are confident using virtual reality technology, who can read and comprehend instructions, and who finish their homework. Consequently, the measurement of these two components of VMedTAAM, PU, and EOU, will indicate whether or not students intend to employ technology in their classes. Acceptance of the technology in this context is very dependent on all aspects of the VMedTAAM architecture.

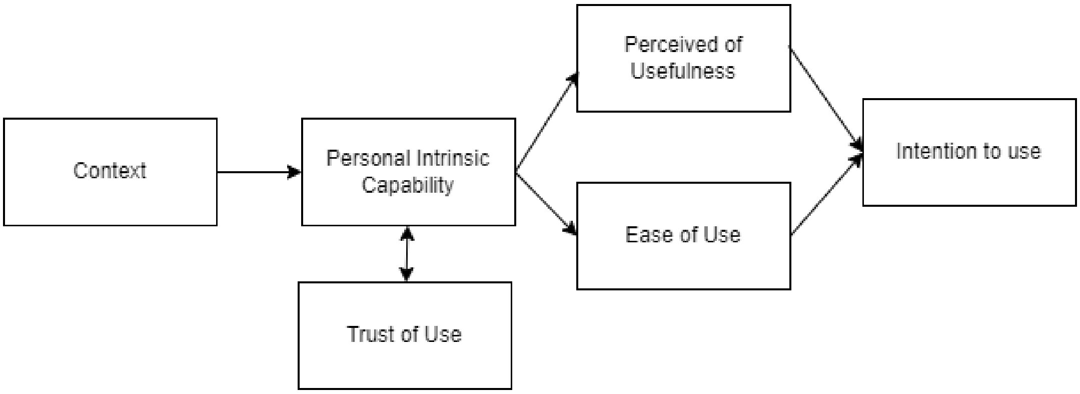

Figure 3: The illustration of the VMedTAAM

METHODOLOGY

This study seeks to construct an instructional design using the cognitive load theory and develop an immersive anatomy medical classroom using VR technology in response to the issues mentioned in the introduction section above. This instructional design and cognitive load theory help to streamline the stimulation content for an anatomy lecture in a new immersive environment. The quantitative approach was used in this study. For the quantitative procedure, a quasi-experimental single-group post-test was also employed. This quantitative method was used to address the research objectives.

The development phase, the implementation phase, and the evaluation phase were the three evaluation phases of this study. 31 students took part in this study by utilizing the quantitative methodology. The students are allowed to independently experience the VR anatomy classroom and get a sense of how the virtual world differs from the actual environment. The students range in age from 19 to 25 years old and primarily study at Universiti Sains Malaysia. The dependent variables are CT, PIC, TU, PU, EOU, and IU.

Before participating in the study, all 31 students were given a brief explanation of virtual reality technology and the handling technique of the VR application. The students then started to experience the VR anatomy classroom. Five to ten minutes were provided to each of the students to experience the VR anatomy classroom. In this VR classroom, the students are given the task of placing the anatomical organs on the table that has been labelled with each part of the body. The heart, respiratory system, digestive system, and brain are the four components of the anatomy that must be correctly positioned.

After completing the activity, students are given a set of questionnaires to answer. A questionnaire that is adapted from TAM which consists of six dimensions including, usefulness, ease of use, trust, context, personal initiatives, and intended use will be used as the instrument to access their technology acceptance. The data will be collected by using a Google form and will be analyzed in SPSS Software version 26 to measure the acceptance of this technology quantitatively. The reliability of the questionnaires is 0.956 and it is an acceptable value as it is higher than 0.6 (Ahdika, 2021). In addition, the reliability of each element of the VMedTAAM is shown in Table 2 below.

Table 1: The reliability of VMedTAAM

The reliability of VMedTAAM	α value
VMedTAAM	0.956

Table 2: The reliability of each component of VMedTAAM by using Cronbach's Alpha

The Components of VMedTAAM	α value
PU	0.837
EOU	0.796
PIC	0.710
TU	0.589
CT	0.821
IU	0.700

RESULT

The following subsection will present the findings of the quantitative analysis. A questionnaire that has been broken down into six sections which are perceived usefulness, ease of use, context, trust of use, personal intrinsic capability, and intention to use is shown in Figure 4.

Received: 1 February 2023; Revised: 5 March 2023; Accepted: 1 April 2023; Published: 1 June 2023

Questions	Element
1. This application is useful for students	**PU**
2. I would find the immersive anatomy classroom to be flexible to interact with	**EOU**
3. I believe this immersive anatomy classroom is risk-free to use	**TU**
4. I am capable of using the application	**PIC**
5. This VR application is easy to handle	**EOU**
6. The VR technology is very relevant for medical and health education	**PU**
7. I have fun using the immersive anatomy classroom	**CT**
8. The content of this immersive anatomy classroom is decreasing the cognitive load	**CT**
9. I could use the application when it is published	**IU**
10. I could use the application if the application is widely acknowledged	**PU**
11. I prefer to be the first one using the anatomy classroom with VR technology	**PIC**
12. I like the interaction between the anatomy body and VR	**EOU**
13. The video inside the classroom is very helpful to increase my knowledge	**PIC**
14. I feel fully immersed in the world of anatomy classroom	**TU**
15. I will share with my friends the experience I gained in this virtual anatomy classroom and recommend them to try this application also	**IU**

Figure 4. The set of VMedTAAM questionnaires

The outcomes of the study have been examined by using SPSS software. The data is then separated into various components. The first three questions (numbered 1, 6, and 10) are classified as PU whereas the next seven (numbered 2, 5, and 12) are classified as EOU. In addition, questions 4, 11, and 13 are associated with PIC, questions 3 and 14 are associated with TU, questions 7 and 8 are associated with CT, and questions 9 and 15 are associated with IU. By classifying the questions into different categories, it is easier for the researcher to conduct an analysis.

Table 3: The mean comparison among the elements of the VMedTAAM

Elements	N	Minimum	Maximum	Mean	Std. Deviation
PU	31	2	5	4.19	0.980
EOU	31	2	5	4.35	0.798
PIC	31	2	5	4.32	0.909
TU	31	2	5	4.23	0.884
CT	31	3	5	4.48	0.811
IU	31	2	5	4.35	0.839
PU2	31	3	5	4.58	0.672
EOU2	31	2	5	4.23	0.990
PIC2	31	2	5	4.32	0.909
TU2	31	2	5	4.29	0.902
CT2	31	3	5	4.26	0.773
IU2	31	2	5	4.55	0.810
PU3	31	3	5	4.65	0.661
EOU3	31	2	5	4.39	0.844
PIC3	31	3	5	4.39	0.761

Based on the data, the average means are 4.043, while EOU2, which stands for question 5, has the highest standard deviation with a value of 0.990. Despite this, the lowest standard deviation from PU3 is 0.661, which stands for question 10. It indicates that, in contrast to EOU2, where there are no significant gaps between "strongly agree" and "neutral and disagree", the data distribution around the mean is more concentrated. Based on the aforementioned interpretation of the results, the acquired mean values for the questions that collectively reflect the VMedTAAM elements appear to range from 4.19 to 4.65. This shows that the majority of the students who experience this anatomy classroom are comfortable with the incorporation of VR technology.

Additionally, the code element for question 10 (PU3) has the highest mean (4.65), followed by the code element representing question 6 (PU2) (4.58), and the code element representing question 15 (IU2) with mean values of 4.55. Furthermore, the first two with the highest means are related to perceived usefulness when compared to the ease of use. Contrarily, the VMedTAAM elements' total mean is split into a three-item and a two-item dimension. The three-item dimension includes PU, EOU, and PIC, while the two-item dimension consists of TU, CT, and IU. PU has a total mean of 13.42 and is a dominant element for three-item dimensions followed by PIC and EOU with 13.03 in this VMedTAAM as stated in Table 4 below. The result of the three-item dimension demonstrates that the VR anatomy classroom is very useful to the students, followed by the capability of using it and its ease of use. Nevertheless, for the element of the two-item dimension, IU has a higher total mean than CT and TU, with a value of 8.90 versus 8.74 and 8.52, respectively as stated in Table 5. This proved that the students intend to use the VR anatomy classroom in the future.

Received: 1 February 2023; Revised: 5 March 2023; Accepted: 1 April 2023; Published: 1 June 2023

Table 4: The total mean of the VMedTAAM element with 3 items.

Elements	Total Mean
Perceived Usefulness (PU)	13.42
Personal Intrinsic Capability (PIC)	13.03
Ease of Use (EOU)	12.97

Table 5: The total mean of the VMedTAAM element with 2 items.

Elements	Total Mean
Intention of Use (IU)	8.90
Context (CT)	8.74
Trust of Use (TU)	8.52

DISCUSSION AND CONCLUSION

The development of a virtual reality anatomy classroom marked the study's end. An efficient learning platform and products are produced by combining many theories. By looking at the theories of working memory and cognitive load, the design and development of this immersive learning approach will be improvised. As the ADDIE model serves as a complement to Mayer's 12 Multimedia Principles in the development of an immersive virtual reality of an anatomy classroom, the ADDIE model can be seen as a powerful supplement. It also ensures the effectiveness of the VR anatomy classroom in helping students during the lessons. Additionally, based on a guideline from Davis's technology acceptance model (TAM), this paper created VMedTAAM, a novel virtual reality technology acceptance model for anatomy classrooms.

In addition, the VR anatomy classroom is seen to be effective when students can easily complete the tasks given in this immersive virtual learning because of the help of pictures, videos, 3D models that can be touched immersively, and clear instructions given. The students' attitudes show that the combination of the ADDIE model and 12 Mayer's Principles of Multimedia including CP, SCP, and SP succeeded in reducing the cognitive loads. The quantitative results of the technology acceptance proved the success of this design and development.

Moreover, by following the tenets of the aforementioned theories, this application effectively lessens the cognitive load while referring to the study's outcomes. This application is deemed appropriate for usage because the mean value ranges between 4.19 and 4.65, which corresponds to "agree" responses for all VMedTAAM questionnaire items. However, there are many things to undertake to investigate the optimal framework architecture for developing immersive learning technologies. The integration of numerous theories in this study will aid future researchers in VR technology, especially in the medical science field. Recommendations for future research include employing mixed-method approaches to investigate related technologies, such as the motivation and behaviour of students to utilize VR technology in medical sciences, particularly for anatomy.

The government should take the results of this study seriously since, nowadays, the alpha generation grows closely with gadgets. Moreover, the world is moving to Web 3.0, which consists of five main components, including Metaverse. The Metaverse is a digital representation of the physical world and the Internet in three dimensions (Vermaak, 2022). Users can move around using their laptops, mobile devices, or VR/AR headsets, creating a truly immersive experience that will push the bounds of reality further and further apart. Thus, students and educators must be aware of Web 3.0 and the Metaverse, which contain VR technology, such as giving exposure to this technology.

ACKNOWLEDGMENT

This work was supported by the Universiti Sains Malaysia (Short Term Grant) [304.PMEDIA.6315301], Centre for Instructional Technology & Multimedia, and Institute of Postgraduate Studies.

REFERENCES

Ahdika, A. (2021). Improvement of Quality, Interest, Critical, and Analytical Thinking Ability of Students through the Application of Research Based Learning (RBL) in Introduction to Stochastic Processes Subject. *International Electronic Journal of Mathematics Education*, *12*(2), 167–191. https://doi.org/10.29333/iejme/608

Albus, P., Vogt, A., & Seufert, T. (2021). Signaling in virtual reality influences learning outcome and cognitive load. *Computers and Education*, *166*(April 2020), 104154. https://doi.org/10.1016/j.compedu.2021.104154

Aldoobie, N. (2015). ADDIE Model. *American International Journal of Contemporary Research ADDIE*, *5*(6), 68–72.

Anmarkrud, Ø., Andresen, A., & Bråten, I. (2019). Cognitive Load and Working Memory in Multimedia Learning: Conceptual and Measurement Issues. *Educational Psychologist*, *54*(2), 61–83. https://doi.org/10.1080/00461520.2018.1554484

Basu, R. (2018). Instructional Design Models : Benefits and Challenges. *UGC Approved Journal*, *Vol.-41 N*(June), 31–36.

Budoya, C. M., Kissaka, M., & Mtebe, J. (2019). Instructional Design Enabled Agile Method Using ADDIE Model and Feature Driven Development Process. *International Journal of Education and Development Using Information and Communication Technology*, *15*(1), 35–54.

Chau, P. Y. K., & Hu, P. J. H. (2001). Information technology acceptance by individual professionals: A model comparison approach. *Decision Sciences*, *32*(4), 699–719. https://doi.org/10.1111/j.1540-5915.2001.tb00978.x

Ching, G. S., & Roberts, A. (2020). Evaluating the pedagogy of technology integrated teaching and learning: An overview. *International Journal of Research Studies in Education*, *9*(6). https://doi.org/10.5861/ijrse.2020.5800

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems*, *13*(3), 319–339. https://doi.org/10.2307/249008

Ginns, P., & Leppink, J. (2019). Special Issue on Cognitive Load Theory: Editorial. *Educational Psychology Review*, *31*(2), 255–259. https://doi.org/10.1007/s10648-019-09474-4

Hamizi, M. A. A. B. M., Mokmin, N. A. B. M., & Ariffin, U. H. binti. (2022). *Virtual reality technology in physical education : a systematic review in instructional design & implementation Muhammad Aminuddin Akmal Bin Mohd Hamizi , Nur Azlina Binti Mohamed Mokmin *, and Ummie*. *6*(1), 6–12. https://doi.org/10.26666/rmp.ajtve.2022.1.2

Hsieh, M. C., & Lee, J. J. (2018). Preliminary Study of VR and AR Applications in Medical and Healthcare Education. *Journal of Nursing and Health Studies*, *03*(01), 1–5. https://doi.org/10.21767/2574-2825.100030

Kassutto, S. M., Baston, C., & Clancy, C. (2021). Virtual, Augmented, and Alternate Reality in Medical Education: Socially Distanced but Fully Immersed. *ATS Scholar*, *2*(4), 651–664. https://doi.org/10.34197/ats-scholar.2021-0002re

Kavanagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A Systematic Review of Virtual Reality in Education. *Themes in Science and Technology Education*, *10*(2), 85–119.

Lauren, H. (2021, December 14). *Mayer's 12 Principles of Multimedia Learning | Lucidea*. LUCIDEA. https://lucidea.com/blog/mayers-12-principles-of-multimedia-learning/

Lin, H. T., Tsai, H. J., Li, Y. I., & Hu, W. P. (2022). Benefits of applying virtual reality in pelvic movement training through a Wii Fit: a randomized controlled trial. *BMC Medical Education*, *22*(1), 1–11. https://doi.org/10.1186/s12909-022-03109-z

May, A. (2018, March 7). *Instructional Design Models: Comparing ADDIE, Bloom, Gagne, & Merrill*. DASHE & THOMSON. https://www.dashe.com/blog/instructional-design-models-comparing-addie-bloom-gagne-merrill

Mutlu-Bayraktar, D., Cosgun, V., & Altan, T. (2019). Cognitive load in multimedia learning environments: A systematic review. *Computers and Education*, *141*(June), 103618. https://doi.org/10.1016/j.compedu.2019.103618

Nurul Fadly, H., Tuan Waheda, T. C., & Ummu Aiman, M. (2022). *Industrial and Management Practices : Learning , Quality and Environmental Improvement* (Issue January).

Nurul, N. M. K., Adnan, A. H. M., Yusof, A. A., Ahmad, M. K., & Anwar, M. K. (2019). Immersive Interactive Educational Experiences – Technologies for Malaysian Universities. *Proceedings: International Invention, Innovative & Creative (InIIC) Conference, 2019 MNNF Publisher (ISBN Number: 978-967-15509-9-1)*, *2019*, 190–196.

Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology*, *110*(6), 785–797. https://doi.org/10.1037/EDU0000241

Qingtao, Z. (2020). Analysis and Research on the Combination of Virtual Reality Technology (VR) and College Sports Training. *Journal of Physics: Conference Series*, *1486*(5). https://doi.org/10.1088/1742-6596/1486/5/052011

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers and Education*, *147*(November 2019), 103778. https://doi.org/10.1016/j.compedu.2019.103778

Samadbeik, M., Yaaghobi, D., Bastani, P., Abhari, S., Rezaee, R., & Garavand, A. (2018). The Applications of Virtual Reality Technology in Medical Groups Teaching. *Journal of Advances in Medical Education & Professionalism*, *6*(3), 123–129. http://www.ncbi.nlm.nih.gov/pubmed/30013996%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6039818

Sattar, M. U., Palaniappan, S., Lokman, A., Hassan, A., Shah, N., & Riaz, Z. (2019). Effects of virtual reality training on medical students' learning motivation and competency. *Pakistan Journal of Medical Sciences*, *35*(3), 852–857. https://doi.org/10.12669/pjms.35.3.44

Shirley, H. (2022). *Cognitive Load Theory and Phonics Instruction | Phonics Hero*. Phonics Hero. https://phonicshero.com/cognitive-load-theory-phonics/

Suh, A., & Prophet, J. (2018). The state of immersive technology research: A literature analysis. *Computers in Human Behavior*, *86*, 77–90. https://doi.org/10.1016/j.chb.2018.04.019

Surendran, P. (2013). Technology Acceptance Model: A Survey of Literature. *International Journal of Business and Social Research*, *2*(4), 175–178. https://doi.org/10.18533/ijbsr.v2i4.161

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review*, *31*(2), 261–292. https://doi.org/10.1007/s10648-019-09465-5

Vermaak, W. (2022). *What Is Web 3.0? | Alexandria*. https://coinmarketcap.com/alexandria/article/what-is-web-3-0

Vesga, J. B., Xu, X., & He, H. (2021). The effects of cognitive load on engagement in a virtual reality learning environment. *Proceedings - 2021 IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2021*, 645–652. https://doi.org/10.1109/VR50410.2021.00090

White, N., & Candidate, D. (2018). *Cognitive load theory & Instructional design in computer- assisted field orientations | Step 2*.

Zawacki-Richter, O., & Latchem, C. (2018). Exploring four decades of research in Computers & Education. *Computers and Education*, *122*(June 2017), 136–152. https://doi.org/10.1016/j.compedu.2018.04.001

Zhang, X., Shi, Y., & Bai, H. (2021). *Immersive Virtual Reality Physical Education Instructional Patterns on the Foundation of Vision Sensor*. *2021*.

Zhao, J., Xu, X., Jiang, H., & Ding, Y. (2020). The effectiveness of virtual reality-based technology on anatomy teaching: A meta-analysis of randomized controlled studies. *BMC Medical Education*, *20*(1), 1–10. https://doi.org/10.1186/s12909-020-1994-z