Development of Augmented Reality (AR) for Innovative Teaching and Learning in Engineering Education

Nur Idawati Md Enzai[1*], Norhayati Ahmad[2], Mohd Amir Hamzah Ab. Ghani[3] , Siti Sara Rais[4] , Syazilawati Mohamed[5]

[12345] Faculty of Electrical Engineering, Universiti Teknologi MARA,
23000 Dungun, Terengganu, Malaysia
nurid333@uitm.edu.my, norha291@uitm.edu.my, mohdamirhamzah@uitm.edu.my, sitisara851@uitm.edu.my, syazilawati@uitm.edu.my
[*]Corresponding Author

https://doi.org/10.24191/ajue.v16i4.11954

Received: 15 November 2020
Accepted: 11 December 2020
Date Published Online: 24 January 2021
Published: 25 January 2021

Abstract: Engineering education in particular involves laboratory equipment and apparatus which requires safety procedures and substantial financial cost. Recent pandemic has also affected engineering education teaching and learning processes as all the classes and laboratory sessions need to be conducted via online distance learning (ODL) method. Therefore, this research selects Augmented Reality (AR) Method for innovative teaching and learning process. AR is known for its ability to overlay rich media into the real world by viewing through web-enabled devices such as phones and tablets, making it accessible anywhere anytime. In addition to improving interest and motivation of students during the learning process, AR could also address the financial and space constraints pertaining to science and technology laboratory equipment and apparatus. In this research, an AR has been developed according to system development method by using Assemblr application. The developed AR system is then given to selected educators to be evaluated in terms of their awareness and the system's usability. The educators' responses are obtained through a questionnaire survey and the findings are then analysed and presented in this paper. The responses are taken into account for improving the AR system and the development process will be continued in parallel with more testing. The final prototype will then be implemented in real classes in the future.

Keywords: Augmented Reality, Education, Engineering

1. Introduction

The integration of technology in our daily routine has immensely increased over the last decade as our society finds its new way of living especially during the global pandemic time. The repercussion of it served as a catalyst to technologists and innovators to devise a fresh approach in easing our way of life. Studies done during the pandemic to determine the university student's readiness in learning everything through online methods show that the students were between slightly and moderately ready for online learning and some were not fully ready mostly due to infrastructure constraints which leads to hindrance in learning (Chung, Subramaniam, & Dass, 2020). The emotional and psychological states of students must also be maintained while employing any online learning tool or platform (Samat, Awang, Hussin, & Nawi, 2020).

Several fields of study would require less face-to-face interaction but on the up side, this is a situation where technology would excel by introducing fun and interactive ways of problem-based learning. The widely available Augmented Reality (AR) used to be regarded as complex and hard to handle but technology did improve and it has become more accessible through various platforms.

AR also worked well in education, in particular when it comes to courses which involve mechanisms of machinery and systems as well as complicated theories (Bower, Howe, McCredie, Robinson, & Grover, 2014). On the other hand, (Akçayır & Akçayır, 2017) highlighted the challenges for incorporating AR in education. Among the identified issues are usability and pedagogy. A well-planned AR is expected to improve the learning process especially for science and engineering subjects as they involve substantial amounts of equipment and apparatus. In addition to ability to address the issue of lack of resources due to financial and space constraints, safety of students can also be assured through minimal practice of dangerous experiments (Martín-Gutiérrez, Fabiani, Benesova, Meneses, & Mora, 2015).

The studies from a series of focus groups show that this method of learning process would improve the understanding of a subject through instantaneous examples shown and interactivity of the system. The challenges that could hamper the progress of mixed reality education are apparent such as the scarcity of appropriate technical infrastructure and the costly content development process that affect both educators and students (Mustafa Kamal, Mohd Adnan, Yusof, Ahmad, & Mohd Kamal, 2019). (Bazarov, Kholodilin, Nesterov, & Sokhina, 2017) conducted studies that aim to improve performance and stimulate learners' motivation through application of AR in their curriculum subjects which involved 24 engineering students. An AR application was developed using Unity 3D and Vuforia. The AR application translates a complex laboratory setup into an AR content where the interactivity focuses on assisting the practical training and showing detailed description of the training system elements. It is concluded that the majority of the learners exhibit a positive attitude towards AR technology (Bazarov et al., 2017).

Mota, Ruiz-Rube, Dodero and Figueidero (2016) present an authoring tool called Visual Environment for Designing Interactive Learning Scenarios (VEDILS) that authorizes users to develop an interactive learning scenarios based on AR (Mota, Ruiz-Rube, Dodero, & Figueiredo, 2016). The tool aims to integrate the AR technology into the educational sphere such as in this case, the students were able to achieve better understanding of 3D graphical projections and the teachers can track the students' activities with voice explanation and required steps to complete the activity. Learning enhancement can also be observed when students use AR. For example, the students can access examples of dangerous situations such as the impact of corrosive chemicals on the real-world environment. AR allows students to explore the virtual object for a longer period of time which makes them become more motivated (Thomas, Linder, Harper, Blyth, & Lee, 2019).

As academic point of view and industrial research are integral, a research was done to determine the success factors and challenges in implementing Industrial Augmented Reality (IAR) systems. 22 experiments were conducted in this study. The experiments use head-mounted devices (HMD) by Microsoft HoloLens which guide through an assembly work. The experiment exploits the capabilities of the HMD to display the accurate assembly procedure in 3D hologram. The results from 15 subjects from the industry and 7 from the university have different implications. The important parts are finding balance in creating increment in productivity and shortening learning time while uncovering new methods or techniques with faster response and solid algorithms (Masood & Egger, 2020).

Based on the reviewed works, it can be derived that AR development is crucial especially for science and engineering education to address the lack of facilities, save financial cost and minimize laboratory hazards. Instead of constructing the AR from scratch, this paper makes use of an app called Assemblr which provides existing tools that can be customized and focuses on the course contents.

2. Methodology

The basic steps involved in developing AR for this course are; creating 3D images and creating AR markers for viewers. The general architecture of AR is shown in Figure 1. By using AR, the users can interact with virtual objects as if the real objects are in front of them. AR can be demonstrated by using a software/app that executes the camera feature and detects a marker with a tracking system. After tracking the marker, a 3D model will be displayed. The position and orientation of the 3D model will be adjusted by the marker so that it appears on the user's mobile device screen. In this research, Assemblr Edu can be used by the students to view the AR images.

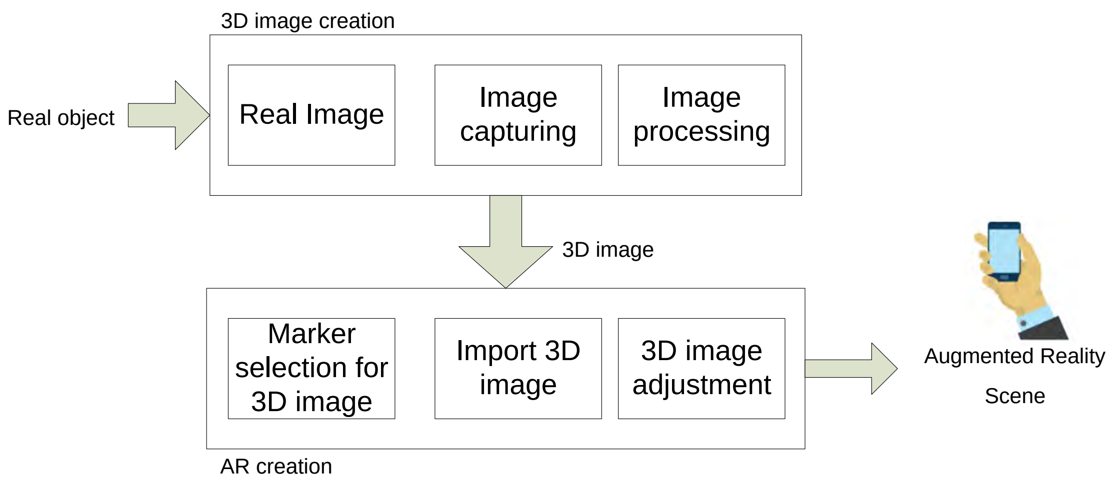


Fig. 1 Block diagram of the AR scene

In this study, we have chosen a few components in a computer's motherboard. Figure 2 shows the methodology in the creation of an AR scene. Based on the real object, a 3D image has been created. After deciding the object to be used in this study, the best pictures taken are used to reconstruct the 3D model. The steps of image processing include the acquisition of 3D information of the object that needs to be modelled. Section 2.1 describes the creation of 3D images. The next step is AR Creation by using Assemblr app as elaborated in section 2.2.

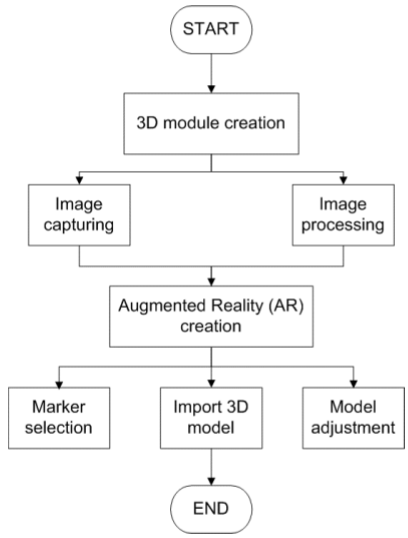
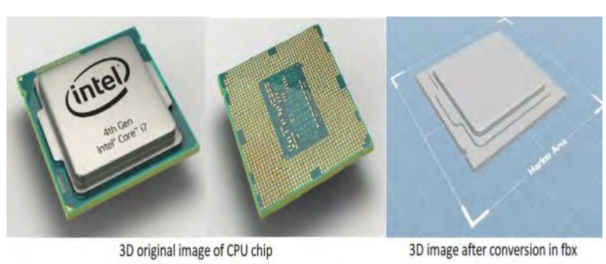


Fig. 2 Flow chart of AR development

2.1 3D Module Creation

3D images can be obtained in formats such as fbx, stl, obj, glb and 3mf. However, only fbx format is compatible with Assemblr app. 3D images can be obtained from websites such as turbosquid.com, vectorstock.com, sketchfab.com, and free3d.com. Even though high-quality 3D images can be obtained from these websites, the free version of Assemblr app can't accommodate large size images.

3D images can also be created using open-source link that converts 2D image into 3D image, for instance http://app.selva3d.com/transform. However the 3D images produced from this link are of stl format. The 3D images need to be converted into fbx format. Due to multiple conversions, the quality of the 3D images has deteriorated as shown in Figure 3(a). Another method to create 3D images is by using Paint3D software. For beginners, the basic 3D shapes such as cube, cylinder and sphere can be selected. To make an image looks realistic, a sticker can be put on the basic shape as shown in Figure 3(b).



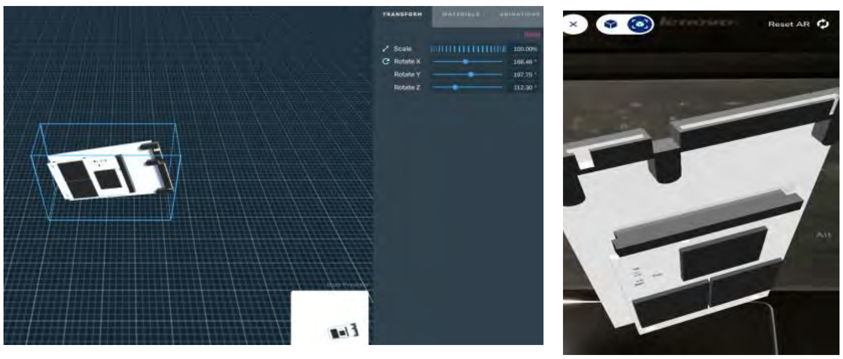
(a)

(b)

Fig. 3 (a) The original 3D image quality is degraded after conversion (b)The 3D image for motherboard power supply is created using Paint3D with sticker

2.2 AR Creation

First, a marker is generated and printed, so the scene can be visualized interactively as it is being created. Then, the 3D model is imported, and it undergoes some adjustment to produce the best AR image. By using AR software like Assemblr Edu, the camera scanner of viewers needs to be activated and pointed to the printed marker. Once AR recognizes the marker, the user can explore the model that has been created. By scanning the generated markers, the 3D objects will appear by using Assemblr App. We have developed the 3D objects of selected components in a computer's motherboard. Figure 4 shows the initial steps involved in our AR development which include adjusting the 3D object depicted in Figure 4(a) and testing AR view in Figure 4(b).



(a) (b)

Fig. 4 (a) 3D object is being adjusted (b) AR view is being tested

3. Results

Microprocessor course is selected for AR implementation in this paper. The introductory chapter which covers the computer hardware including the components in a motherboard is selected for AR contents. Through AR implementation, the students should be able to identify and understand the functions of the components on the motherboard before learning about the microprocessor in detail. This section is divided into three parts: AR demonstration, user experience survey and discussions.

3.1 AR demonstration

Figure 5 shows the 3D objects that appear when their respective markers are scanned. Figure 5(a), 5(b), 5(c) and 5(d) are some components of motherboard namely: CPU chip, SATA, hard drive and graphic card. Each component has its corresponding marker which can be printed and given during face-to-face class session and can also be provided online.

(a) (b) (c) (d)

Fig. 5 AR view of (a) CPU chip (b) SATA (Serial AT Attachment) (c) hard drive (d) graphic card

There are more 3D objects that will be developed. However, due to the limitation of Assemblr App free version used, the imported 3D objects cannot exceed the size of 8MB and only fbx format is accepted as stated in section 2.1. As a result, the image quality is degraded which causes the lack of colour and textures among the 3D objects shown in Figure 5 and Figure 3(a). We plan to resort to a paid version to produce AR of better quality. The project is still in the prototype development level.

3.2 Survey

A survey was conducted to obtain user experience of the developed AR. The survey questions with options of answers are shown in Table 1 below:

Table 1. Survey questions for educators

Criteria	Questions	Options of Answers
Background	Years of experience as an educator	Less than 1 year, 1-5 years, 6-10 years, More than 10 years
	Area(s) of research interest	Subjective (open ended)
Awareness	I have heard about AR before. I know how AR functions.	Strongly agree, Agree,
Usability	Students can be more interested in learning by using this AR. The interface of this AR is user friendly.	Neutral, Disagree, Strongly disagree,
Suggestion	Comments for enhancement.	Subjective (open ended)

This survey aims to obtain user experience responses from selected educators of Electrical Engineering courses. Conducting survey is one of the alpha testing methods in the stage of the delivery multimedia project (Vaughan, 2014). Even though this project is still in the phase of feasibility study, the preliminary findings are important to get the comprehensive perspective of AR implementation so that the project can proceed further. If the findings are found to be very negative, the project should not be continued or may require significant revisions.

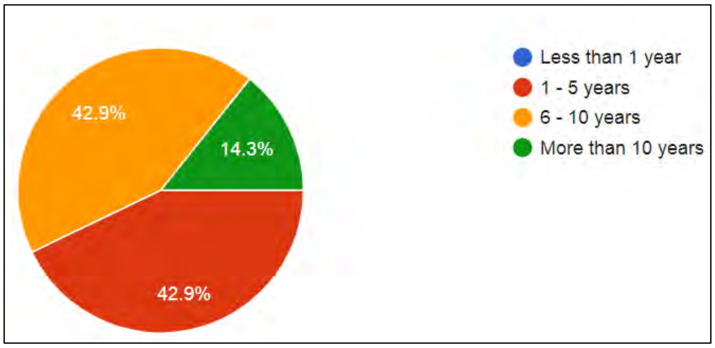


Fig. 6 Responses on working experience

For the initial testing, seven educators have tested the developed AR and then answered the survey to provide their perceptions. Based on Figure 6, almost 85% respondents have more than five years experience and the other respondents have worked as educators for less than five years.

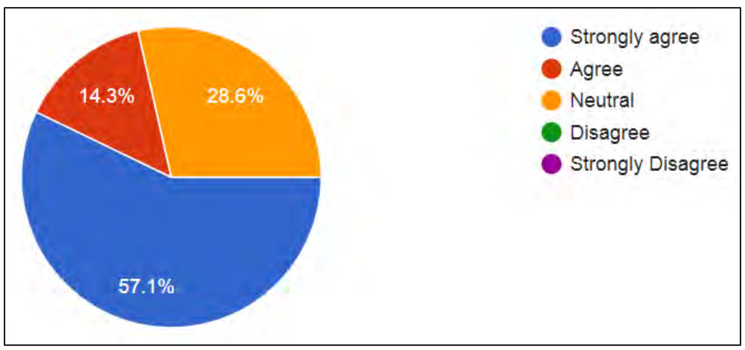


Fig. 7 Responses to question: I have heard about AR before

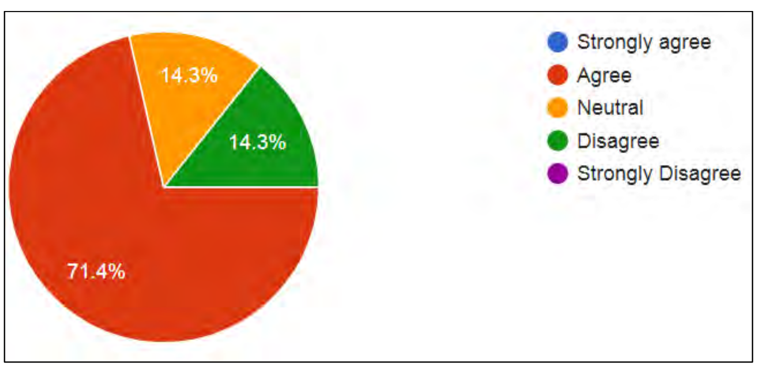


Fig. 8 Responses to question: I know how AR functions

Figure 7 and 8 show the responses regarding their awareness of AR. The awareness questions are designed to check the familiarity of respondents with AR. More than 70% answered agree and strongly agree for the first question, indicating that the majority of the respondents already know about AR. More than 70% of respondents also agree and strongly agree that they know the basic operation of AR.

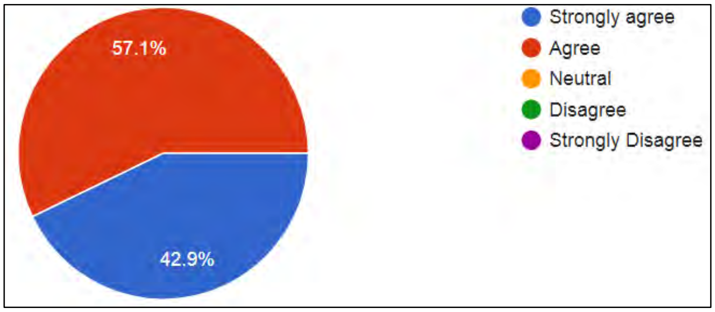


Fig. 9 Responses to question: Students can be more interested in learning by using this AR

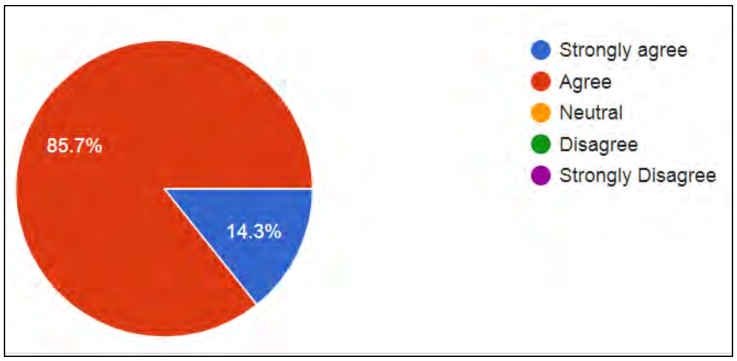


Fig. 10 Responses to question: The interface of this AR is user friendly

Meanwhile, Figure 9 and 10 show the responses related to usability of the developed AR. In terms of usability criterion, all respondents agree that AR can increase the interest of students in learning. This is aligned with the findings by (Rizov & Rizova, 2015). A study by (Khan, Johnston, & Ophoff, 2019) also verified that AR could increase the learning motivation of students in terms of attention, satisfaction and confidence. In our survey, the user-friendliness of the AR interface is also acknowledged by all respondents. None of the respondents chose neutral, disagree and strongly disagree.

Even though the overall responses show that our developed AR is well received by the educators, there are some suggestions that highlight the room for improvement. The time to load each object may need to be reduced and animation videos are suggested to be added in the AR for better visualization. The survey responses for this initial testing will be taken into account for further development and more testing will be conducted with a larger number of respondents.

In conclusion, as the survey shows positive feedback by the respondents, this means that this project can be continued by improving the existing system up to the delivery stage where beta testing can be performed by students who will be using this AR.

3.3 Discussions

Since central processing unit (CPU) or microprocessor is one of the primary components and also the most complex component in the computer system, it is quite challenging to provide a learning environment that can ensure students' learning engagement continuously because the course materials are very theoretical and difficult to visualise (Abd Majid, Mohammed, & Sulaiman, 2015). Hence, microprocessor courses are selected for AR implementation as an induction set to cultivate students' interest.

Teaching and learning computer system hardware components requires real devices. As such, it involves financial costs. With the use of AR, the cost of purchasing components can be reduced. Furthermore, it can be easily accessed online using a smartphone, especially during pandemic situations where ODL is used as a teaching and learning method. The use of AR has proven its effectiveness in engaging students in the learning process as reported in the previous research (Nizar, Rahmat, Maaruf, & Damio, 2019).

4. Conclusion

This work presents the development of AR to address the facilities constraints, safety issues and to increase interest of students in the teaching and learning process. Space constraints, safety procedures and lack of facilities are very relevant to engineering education. As AR can be utilized anywhere and it provides virtual experience instead of physical contact with laboratory equipment, AR has become a suitable solution to challenges in engineering education. Therefore, an AR has been developed for microprocessor courses by using computer hardware components as the contents. Several educators in engineering courses have been selected to experience AR demonstration for initial testing of the developed AR. The obtained responses indicate that the developed AR is well received and perceived as having potential to engage students more in the teaching and learning process. In the future, the developed AR will be improved based on the respondents' feedback and will undergo more testing with larger numbers of respondents including educators and students before being implemented in real classes.

5. Acknowledgements

Special acknowledgment goes to Universiti Teknologi MARA (UiTM) Cawangan Terengganu Kampus Dungun for the Special Interest Group Grant, (SIG) - 600-UITMCTKD (PJI/RMU/ST/DANA SIG 5/2/1) Jld.4 Dst (05/2019) for funding the research activities.

6. References

Abd Majid, N. A., Mohammed, H., & Sulaiman, R. (2015). Students' perception of mobile augmented reality applications in learning computer organization. *Procedia-Social and Behavioral Sciences, 176*, 111-116.

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review, 20*, 1-11.

Bazarov, S., Kholodilin, I. Y., Nesterov, A., & Sokhina, A. (2017). Applying Augmented Reality in practical classes for engineering students. Paper presented at the *IOP Conference Series: Earth and Environmental Science*.

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education–cases, places and potentials. *Educational Media International, 51*(1), 1-15.

Chung, E., Subramaniam, G., & Dass, L. C. (2020). Online learning readiness among university students in Malaysia amidst COVID-19. *Asian Journal of University Education, 16*(2), 46-58.

Khan, T., Johnston, K., & Ophoff, J. (2019). The impact of an augmented reality application on learning motivation of students. *Advances in Human-Computer Interaction, 2019*.

Martín-Gutiérrez, J., Fabiani, P., Benesova, W., Meneses, M. D., & Mora, C. E. (2015). Augmented reality to promote collaborative and autonomous learning in higher education. *Computers in Human Behavior, 51*, 752-761.

Masood, T., & Egger, J. (2020). Adopting augmented reality in the age of industrial digitalisation. *Computers in Industry, 115*, 103112.

Mota, J. M., Ruiz-Rube, I., Dodero, J. M., & Figueiredo, M. (2016). Visual environment for designing interactive learning scenarios with Augmented Reality. *International Association for Development of the Information Society*.

Mustafa Kamal, N. N., Mohd Adnan, A. H., Yusof, A. A., Ahmad, M. K., & Mohd Kamal, M. A. (2019). Immersive interactive educational experiences–adopting education 5.0, industry 4.0 learning technologies for Malaysian universities. Paper presented at the *Proceedings of the International Invention, Innovative & Creative (InIIC) Conference, Series*.

Nizar, N. N. M., Rahmat, M. K., Maaruf, S. Z., & Damio, S. M. (2019). Examining the use behaviour of augmented reality technology through Marlcardio: Adapting the Utaut Model. *Asian Journal of University Education, 15*(3), 198-210.

Rizov, T., & Rizova, E. (2015). Augmented reality as a teaching tool in higher education. *International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE)*.

Samat, M. F., Awang, N. A., Hussin, S. N. A., & Nawi, F. A. M. (2020). Online distance learning amidst Covid-19 pandemic among university students. *Asian Journal of University Education, 16*(3), 220-233.

Thomas, R., Linder, K. E., Harper, N., Blyth, W., & Lee, V. (2019). Current and Future Uses of Augmented Reality in Higher Education. IDEA Paper# 81. *IDEA Center, Inc.*

Vaughan, T. (2014). *Multimedia: Making It Work* (9th ed.): McGraw-Hill Education.