Journal of Engineering Science and Technology
Special Issue on ISCoE2023 Vol. 19, No. 2 (2024) 70 - 79

INTEGRATION OF AUGMENTED REALITY BASED ON ANDROID IN THE PROBLEM-SOLVING LABORATORY

ALI ISMAIL[1,*], DEMMY DHARMA BHAKTI[2],
LASMITA SARI[2], LULA DWI KEMALIA[1],AAY SUSILAWATI[1]

[1]Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Institut Pendidikan Indonesia, Indonesia
*Corresponding Author: ali_ismail@upi.edu

Abstract

This research aims to develop a product in the form of an Augmented Reality-integrated Problem-Solving Laboratory model (PSLab-AR). The research method used in this study is research and development. The research design used consisted of the Define, Design, Develop, and Disseminate phases. The participants in this study consisted of three groups: two elementary school teachers, two educational technology experts, along with four elementary school teachers, and 24 sixth-grade students. Based on the needs analysis in the define stage, the PSLab-AR application was required to assist in science learning in elementary school, particularly in providing an engaging representation of the abstract concept of electricity. During the Design and Development stages, we found that the PSLab-AR application product passed the expert evaluation. Furthermore, at the dissemination stage, we found that the application developed had passed portability and usability tests. The usability test showed that this product fulfilled six aspects, namely attraction (2.42), clarity (1.93), efficiency (2.01), accuracy (2.00), stimulation (2.59), and novelty (2.18), all of which scored over 0.8. This indicates that the product has already been applied in science learning in elementary school.

Keywords: Augmented reality, Problem solving laboratory.

1. Introduction

The 21st century is marked by technological advances that significantly change the way we live, work and communicate. Rapid developments in the field of information and communication technology (ICT), such as the internet and smartphones, have become the main driver of change in various fields [1-3]. The use of technology in learning does not only increases accessibility and flexibility but also opens up new opportunities for developing creativity, critical thinking, and collaboration [4-10]. But, technology needs support, especially in the software and facilitation [11-14].

Therefore, the integration of technology in education is key to ensuring that students can face the challenges of the 21st century. One technology that can be used in learning, especially science learning, is augmented reality (AR) technology [15]. Many reports on AR have been documented [16-17].

The development of AR technology is still rarely used in physics laboratories [18]. So far, the application of AR technology in some countries such as Turkey, China, and Mexico is still limited to the form of instructional media [19-23]. A similar situation is happening in Indonesia, where it has not yet been directly integrated into laboratory practices [24, 25]. In fact, technology can improve student's understanding, especially facing with laboratory [26, 27]. Laboratory practices, which serve as the main source of learning for students, can be better optimized by integrating AR technology as a technology-based modality. The importance of integrating AR into laboratory practices is based on several reasons. Firstly, it adds multimodality in representing concepts [28].

Through the integration of AR, modalities in the form of interactive phenomena can be accessed directly by students in the laboratory with the help of technology. For example, students can access the motion of electrons in an electrical circuit when modalities in the form of AR are provided in the laboratory. Secondly, AR provides a different experience for students by immersing them in an environment that combines the real and virtual worlds [13]. Thirdly, it enhances students' understanding in grasping abstract concepts due to dynamic visualization while learning with AR technology [29].

This research aims to develop a product in the form of an Augmented Reality-integrated Problem-Solving Laboratory model (PSLab-AR). This research product is expected to provide new insight into training problem-solving skills and students' levels of understanding, especially for science concepts, because with Augmented reality technology developed, abstract concepts will be easier for students to understand [30]. and the practical problem-solving model can train students' problem-solving skills [31].

2. Theory

The purpose of developing the PSLab-AR model is to enhance students' understanding at a more comprehensive level. Currently, the majority of students only understand concepts in a macroscopic way [32]. Therefore, innovation is needed to enable students to comprehend concepts not only at a macroscopic but also at a microscopic level [33]. Understanding microscopic concepts can be enhanced through the visualization of electron movement through AR technology. The behavior of particle motion needs to be visualized with AR technology because many students still believe that electric current is the flow of positive charge from the positive pole of the battery to the negative pole of the battery [34].

In this research, four-electron movement animations were developed, including: 1) electron movement in marker-less 1 battery, 2) electron movement in marker-less 3 batteries, 3) electron movement in marker-less 3 batteries with a resistor in the circuit. The difference in electron movement animations lies in their speed. The electron movement in marker-less 1 batteries is slower compared to marker-less 3 batteries, and similarly, the electron movement in marker-less 3 batteries with a resistor has a slower electron speed compared to marker-less 3 batteries.

3. Research Method

The research method used in this study is the Define, Design, Develop, and Disseminate (4D). The first stage of this research is the define stage, which involves needs analysis. The analysis was conducted through interviews with teachers to obtain information regarding the use of technology in practicum, and by reviewing literature on innovative technologies that can enhance problem-solving skills and improve students' conceptual understanding. Additionally, content analysis was performed to determine which materials are suitable for the developed AR.

The next stage is the design stage, where a storyboard is developed for the AR application that will be integrated into the laboratory activities. The Development stage aims to develop the application product, followed by validation by experts on the developed product. Finally, the dissemination stage involves testing the developed PS-AR Lab product on various Android devices and conducting trials with elementary school teachers and students. The participants in this study consist of three groups. The first group in the define stage comprises 2 elementary school teachers. The second group of participants, during the design and development stages, were two educational technology experts. Lastly, in the dissemination stage, there are four elementary school teachers and 24 sixth-grade students aged between 11 and 12 years. The participants in this research were selected using purposive sampling techniques.

The instrument used in the define stage is a semi-structured interview with elementary school teachers. The data obtained is then analyzed using thematic analysis. The instrument used in the dissemination stage is the User Experience Questionnaire (UEQ). This questionnaire consists of 26 statements outlined by six indicators. The assessment in the questionnaire is then categorized into three value categories: if > 0.8, the evaluation of the developed application is considered positive; if the value is between -0.8 and 0.8, the evaluation is categorized as neutral; and if <-0.8, the evaluation is categorized as negative.

4. Results and Discussion

4.1. Define stage

The first stage in this research is the define stage. The necessity analysis in this research was conducted using field studies through semi-structured interviews with two teachers in the Garut Regency. Based on the interview results, teachers in schools have not yet implemented technology in laboratory activities. These findings are in line with other research findings, which indicate that only 25% of teachers have integrated technology into physics laboratories [12]. However, the use of technology is crucial in learning, especially in the 21st century, as the utilization of technology can enhance the quality of education, increase student satisfaction, and reduce practical costs [13].

The current situation in the field does not train problem-solving and the application of technology, which is not suitable for 21st-century learning. There are ten skills that students must possess in 21st-century learning, two of which are problem-solving skills and ICT literacy [20]. Therefore, innovation is necessary to bridge the gap in the field, meeting the demands of 21st-century learning, one of which involves developing an innovative laboratory model, namely PSLab-AR. This is in line with the current literature regarding the use of technology for supporting teaching and learning in the lab [35-37].

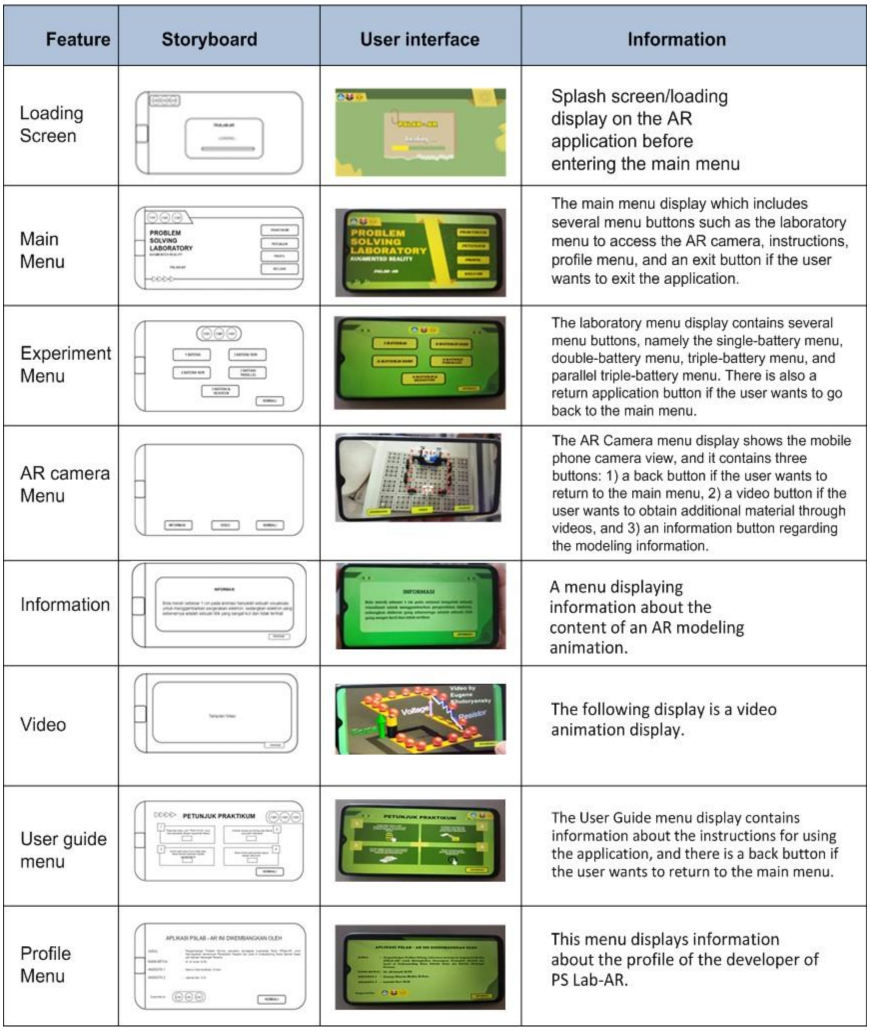
PSLab-AR is an innovative laboratory model that combines the problem-solving laboratory model with augmented reality technology. AR technology is the integration of real and virtual objects in the real environment, operating interactively in real-time, and with the integration of virtual objects in the real world. AR technology has the following characteristics: 1) Combining the real and virtual environment. 2) Operating interactively in real-time. 3) Integrating three dimensions [15]. AR technology is suitable for application in laboratory activities because there is no boundary between the real and virtual world. Based on the advantages of AR technology, the PSLab-AR laboratory model has the following characteristics Exposing students to problems relevant to everyday life and utilizing AR technology to visualize concepts that cannot be seen with the naked eye.

4.2. Design and development stage

The PSLab-AR model in this research was developed with the integration of AR technology. The purpose of this integration is to combine the real environment with the virtual environment in the form of animations [15]. The integration of AR in the laboratory model is carried out during the measurement stage using markerless markers on the electrical KIT laboratory equipment. The design stages of the integrated AR technology begin with creating a storyboard and application user interface (UI) as shown in Fig. 1.

After creating the UI, the next step is to create the AR application, with the development steps. The development of AR technology applications used in this research employs markerless tracking [38], while the virtual objects displayed in the application are in the form of 3D animated objects and YouTube videos. The first step in developing this AR technology is to scan a real object that will be used as markerless using Polycam software. The scan result is then exported into OBJ (Wavefront Object), and FBX (Filmbox) file formats so that the marker-less file can be used as an AR marker in Unity software. The 3D animation is created directly in Unity software. All the components are then imported into Unity software to be combined into an application that can be used on an Android smartphone.

The developed application is then validated by two experts to obtain feedback regarding the content of the developed application so that the application can be improved. Some of the suggestions made by the experts include removing the animation about parallel 3 batteries for elementary and junior high school levels and leaving only 4 buttons in the laboratory menu (see Fig. 2). Additionally, to avoid misconceptions about electrons, it is recommended to add an information menu when students use the AR camera menu.



Feature	Storyboard	User interface	Information
Loading Screen			Splash screen/loading display on the AR application before entering the main menu
Main Menu			The main menu display which includes several menu buttons such as the laboratory menu to access the AR camera, instructions, profile menu, and an exit button if the user wants to exit the application.
Experiment Menu			The laboratory menu display contains several menu buttons, namely the single-battery menu, double-battery menu, triple-battery menu, and parallel triple-battery menu. There is also a return application button if the user wants to go back to the main menu.
AR camera Menu			The AR Camera menu display shows the mobile phone camera view, and it contains three buttons: 1) a back button if the user wants to return to the main menu, 2) a video button if the user wants to obtain additional material through videos, and 3) an information button regarding the modeling information.
Information			A menu displaying information about the content of an AR modeling animation.
Video			The following display is a video animation display.
User guide menu			The User Guide menu display contains information about the instructions for using the application, and there is a back button if the user wants to return to the main menu.
Profile Menu			This menu displays information about the profile of the developer of PS Lab-AR.

Fig. 1. Storyboard and user interface of the application.

Fig. 2. The result of the expert's revision

4.3. Dissemination of AR

In this dissemination stage, two methods are used: portability and usability testing. Usability testing involves disseminating the developed PSLab-AR to users, while portability testing involves disseminating PSLab-AR to various devices.

Portability test: Portability testing is a type of software testing conducted to evaluate the extent to which software or computer systems can be moved from one environment to another without encountering issues. Portability testing is performed on the aspect of installability. This aspect is tested by installing, running, and uninstalling the application on various devices and OS versions, ranging from Android version 9 to Android version 13. The test results are shown in Table 6. Based on Table 6, it can be concluded that the PSLab-AR application was successfully installed and uninstalled on 5 different sample devices. Therefore, it can be inferred that the application meets the installability standard with a 100% or valid percentage.

Table 1. The results of the application testing on various devices and operating systems

No.	Devices	Android types	Install	Uninstall
1	Realme 8i	13	Successful	Successful
2	Vivo Y21	12	Successful	Successful
3	Oppo A16K	11	Successful	Successful
4	Galaxy A10 s	10	Successful	Successful
5	Samsung Galaxy J4+	9	Successful	Successful

Usability test: This usability test is a test to see user responses regarding the software's ability to be understood, learned, used, and appealing to users. This test uses the UEQ questionnaire consisting of 26 questions and is disseminated to 24 students and 4 teachers. The data obtained from the dissemination results are shown in Table 7. Based on the dissemination results to users, data was obtained that the values of all aspects are > 0.8, meaning that this application received positive ratings from users, both teachers and students. Of the six aspects evaluated, the stimulus aspect received the highest value (2.59) overall, and the highest rating according to students (2.63). One of the aspects evaluated in the stimulus is that this application is appealing to use. This is in line with previous research stating that AR technology when applied to learning, can increase students' interest and motivation [38]. Meanwhile, the clarity aspect obtained the lowest value for the overall score (1.92), students (1.91), and teachers (2.00). However, the lowest value of the evaluated aspect is still far above 0.8, meaning that overall, the developed application received positive ratings and is suitable for use and further implementation in practical activities.

Table 2. Analysis of UEQ.

Aspects	Students	Teachers	Overall
Attractiveness	2.382	2.625	2.417
Clarity	1.917	2.000	1.929
Efficiency	1.958	2.313	2.009
Dependability	1.969	2.250	2.000
Stimulation	2.635	2.375	2.598
Novelty	2.125	2.563	2.188

5. Conclusions

Based on the analysis stage, it can be concluded that the situation in the field is still not ideal and does not meet the demands of 21st-century learning. Based on the results of interviews with teachers in the school, technology has not been integrated into practical activities. Therefore, further research is needed to develop augmented reality applications that can train students' level of understanding. Based on the design stage, this practicum model is based on the PS Lab framework, integrating AR technology in the measurement stage (data collection). Integration is carried out to visualize the concept of electron movement in an electrical circuit.

In this development stage, AR technology uses Polycom software to create a markerless system and Unity software to create applications. In the dissemination stage, the PSLab-AR application has a success rate of 100% when installed on various Android systems, meaning that the PSLab-AR application does not have practical issues when running on phones to support practicum activities. Furthermore, the PSLab-AR application passed the usability test with a score >0.8 for all six aspects, namely attraction (2.42), clarity (1.93), efficiency (2.01), accuracy (2.00), stimulus (2.59), and novelty (2.18).

Acknowledgment

The research has been funded by the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia on the Collaborative Research Scheme in 2023.

References

1. Shah, S.S. (2022). Teaching and learning with technology: Effectiveness of ICT integration in schools. *Indonesian Journal of Educational Research and Technology*, 2(2), 133-140.
2. Jadhav, P.; Gaikwad, H.; and Patil, K.S. (2022). Teaching and learning with technology: Effectiveness of ICT integration in schools. *ASEAN Journal for Science Education*, 1(1), 33-40
3. Rachmawati, R. (2019). Utilization and quality of information system for administration services based on ICT in Patehan, Kraton, Yogyakarta. *Indonesian Journal of Science and Technology*, 4(1), 55-63.
4. Akinoso, S.O. (2023). Motivation and ICT in secondary school mathematics using unified theory of acceptance and use of technology model. *Indonesian Journal of Educational Research and Technology*, 3(1), 79-90.
5. Bolaji, H.O.; and Jimoh, H.A. (2023). Usability and utilization of ICT among educational administrators in secondary students in public school. *Indonesian Journal of Educational Research and Technology*, 3(2), 97-104.
6. Bolaji, H.O.; and Onikoyi, O.A. (2024). Usability of ICT for class size remediation and learning among secondary schools. *Indonesian Journal of Educational Research and Technology*, 4(1), 23-28.
7. Bouasangthong, V.; Phonekeo, S.; Soukhavong, S.; Thalungsy, K.; Phongphanit, T.; Vathana, P.; Channgakham, P.; Dyvanhna, S.; Sybounheaung, K.; and Phengphilavong, C. (2024). An investigation into the conditions of ICT application at the teacher education. *Indonesian Journal of Educational Research and Technology*, 4(1), 89-104.

8. Dwiana, O.; Muktiarni, M.; and Mupita, J. (2022). Improved information literacy of elementary school students about living pharmacies through information and communication media (ICT). *ASEAN Journal of Science and Engineering Education*, 2(3), 193-198.
9. Daramola, F.O. (2023). Utilization of ICT resources for teaching among some selected lecturers in colleges of education in Kwara State. *ASEAN Journal of Educational Research and Technology*, 2(1), 1-10.
10. Bolaji, H.O.; and Ajia, I.S. (2023). Information and communication technology (ICT) integration: A veritable technique for quality secondary education. *ASEAN Journal of Educational Research and Technology*, 2(2), 137-144.
11. Ahillon Jr, R.C.; and Aquino, P.M.M. (2023). An assessment strategy using visual basic application in PowerPoint: A free interactive quiz application for ICT class. *Indonesian Journal of Teaching in Science*, 3(2), 183-190.
12. Sanni, A.M. (2023). ICT tools for teaching the Arabic language. *ASEAN Journal of Religion, Education, and Society*, 2(2), 67-74.
13. Bolaji, H.O.; and Adeoye, M.A. (2022). Accessibility, usability, and readiness towards ICT tools for monitoring educational practice in secondary schools. *Indonesian Journal of Multidiciplinary Research*, 2(2), 257-264.
14. Molnár, G.; Szűts, Z.; and Biró, K. (2018). Use of augmented reality in learning. *Acta Polytechnica Hungarica*, 15(5), 209-222.
15. Bangkerd, P.; and Sangsawang, T. (2021). Development of augmented reality application for exercise to promote health among elderly. *Indonesian Journal of Educational Research and Technology*, 1(3), 77-80.
16. Albar, C.N.; Widiansyah, M.G.; Mubarok, S.; Aziz, M.A.; and Maulana, H. (2021). Application of augmented reality technology with the fuzzy logic method as an online physical education lecture method in the new normal era. *Indonesian Journal of Multidiciplinary Research*, 1(1), 35-40.
17. Ismail, A.; Setiawan, A.; Suhandi, A.; and Rusli, A. (2019, November). Profile of physics laboratory-based Higher Order Thinking skills (HOTs) in Indonesian high schools. In *Journal of Physics: Conference Series*, 1280 (5), 052053.
18. Ibáñez, M. B.; Portillo, A. U.; Cabada, R. Z.; and Barrón, M. L. (2020). Impact of augmented reality technology on academic achievement and motivation of students from public and private Mexican schools. A case study in a middle-school geometry course. *Computers and Education*, 145, 103734.
19. Mustafa Fidan, M. T. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Comput. Educ.;* vol. 142, p. 103635.
20. Chang, S. C.; and Hwang, G. J. (2018). Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions. *Computers and Education*, 125, 226-239.
21. Ismail, A.; and Amalia, I. F. (2021). Penerapan model pembelajaran problem solving berbantuan augmented reality untuk meningkatkan pemahaman konsep mahasiswa pada mata kuliah fisika umum. *Jurnal Petik*, 7(2), 87
22. Ismail, A.; Festiana, I.; Hartini, T. I.; Yusal, Y.; and Malik, A. (2019, February). Enhancing students' conceptual understanding of electricity using

learning media-based augmented reality. In *Journal of Physics: Conference Series*, 1157 (3) 032049.

23. Wu, H. K.; Lee, S. W. Y.; Chang, H. Y.; and Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers and education*, 62, 41-49.
24. Sutarno, S.; Setiawan, A.; Suhandi, A.; Kaniawati, I.; and Putri, D. H. (2017). Keterampilan pemecahan masalah mahasiswa dalam pembelajaran bandul fisis menggunakan model problem solving virtual laboratory. *Jurnal Pendidikan Fisika Dan Teknologi*, 3(2), 164-172.
25. Anam, R. S.; Gumilar, S.; and Widodo, A. (2023). The use of the Constructivist Teaching Sequence (CTS) to facilitate changes in the visual representations of fifth-grade elementary school students: A case study on teaching heat convection concepts. *International Journal of Science and Mathematics Education*, 1-27.
26. Kurnaz, M. A.; and Eksi, C. (2015). An analysis of high school students' mental models of solid friction in physics. *Educational Sciences: Theory and Practice*, 15(3).
27. Asy'ari, M. (2016). Identifikasi miskonsepsi mahasiswa pendidikan fisika pada materi rangkaian listrik. *Lensa: Jurnal Kependidikan Fisika*, 4(2), 98-105.
28. Binkley, M.; Erstad, O.; Herman, J.; Raizen, S.; Ripley, M.; Miller-Ricci, M.; and Rumble, M. (2012). Defining twenty-first century skills. *Assessment and teaching of 21st century skills*, 17-66.
29. Azuma, R. T. (1997). A survey of augmented reality. *Presence: teleoperators and virtual environments*, 6(4), 355-385.
30. Moura, G. M., & Da Silva, R. L. D. S. (2017). Analysis and evaluation of feature detection and tracking techniques using OpenCV with focus on markerless augmented reality applications. Journal of Mobile Multimedia, 12, 291-302.
31. Supriyono, S. (2019). Penerapan ISO 9126 dalam pengujian kualitas perangkat lunak pada E-book. *MATICS: Jurnal Ilmu Komputer dan Teknologi Informasi Journal of Computer Science and Information Technology*, 11(1), 9-13.
32. Roumba, E.; and Nicolaidou, I. (2022). Augmented reality books: motivation, attitudes, and behaviors of young readers. *International Journal of Interactive Mobile Technologies*, 16 (16), 59-73.
33. Bugarso, J.M.S.; Cabantugan, R.E.; Que-ann, D.T.; and Malaco, A.C. (2021). Students' learning experiences and preference in performing science experiments using hands-on and virtual laboratory. *Indonesian Journal of Teaching in Scienc*e, 1(2), 147-152.
34. Azizah, E.V.; Nandiyanto, A.B.D.; Kurniawan, T.; and Bilad, M.R. (2022). The effectiveness of using a virtual laboratory in distance learning on the measurement materials of the natural sciences of physics for junior high school students. *ASEAN Journal of Science and Engineering Education*, 2(3), 207-214.
35. Sison, A.J.R.N.; Bautista, J.M.; Javier, J.R.; Delmonte, R.J.B.; and Cudera, R.B. (2024). Development and acceptability of virtual laboratory in learning systematics. *ASEAN Journal of Educational Research and Technology*, 3(1), 9-26.

36. Fauziah, S.P.; Suherman, I.; Sya, M.F.; Roestamy, M.; Abduh, A.; Nandiyanto, A.B.D. (2023). Strategies in language education to improve science student understanding during practicum in laboratory: Review and computational bibliometric analysis. *International Journal of Language Education* 5, 4, 409-425.
37. Al Husaeni, D.F.; Al Husaeni, D.N.; Ragadhita, R.; Bilad, M.R.; Al-Obaidi, A.S.M.; Abduh, A.; Nandiyanto, A.B.D. (2023). How language and technology can improve student learning quality in engineering? definition, factors for enhancing students comprehension, and computational bibliometric analysis. *International Journal of Language Education* 6, 4, 445-476.
38. Hanafi, H. F.; Wong, K. T.; Adnan, M. H. M.; Selamat, A. Z.; Zainuddin, N. A.; and Lee Abdullah, M. F. N. (2021). Utilizing Animal Characters of a Mobile Augmented Reality (AR) Reading Kit to Improve Preschoolers' Reading Skills, Motivation, and Self-Learning: An Initial Study. *International Journal of Interactive Mobile Technologies*, 15(24), 94-107.