Journal of Critical Reviews

ISSN- 2394-5125 Vol 7, Issue 12, 2020

MOBILE AUGMENTED REALITY FOR BIOLOGY LEARNING: REVIEW AND DESIGN RECOMMENDATIONS

Mohd H. A. Kalana[1], Syahrul N. Junaini[2], Ahmad H. Fauzi[3]

[1]Student, Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan, Sarawak, Malaysia
[2]Senior Lecturer, Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan, Sarawak, Malaysia
[3]Lecturer, Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan, Sarawak, Malaysia
[**]Corresponding author: syahruln@unimas.my

Received: 11.03.2020 ***Revised: 12.04.2020*** ***Accepted: 13.05.2020***

Abstract
In the last decade, the implementation of mobile Augmented Reality (AR) has transformed the conventional biology classroom environment. However, only limited articles were found to review the learning content of AR applications for learning biology. Thus, this paper presents a review and analysis of the development of mobile AR applications for learning biology. Four articles that reported the development of AR learning apps for biology from indexing databases were analyzed (Scopus = 3, ScienceDirect = 1). In addition, three apps for learning Biology from Google Play were reviewed and recommended. For the implication, we recommend five important features for developing science AR apps. This synthesized review would benefit teachers and educators, thereby suggesting a path for future work.

Keywords: Mobile augmented reality, virtual reality, educational technology, human-computer interaction, STEM, Science education.

DOI: http://dx.doi.org/10.31838/jcr.07.12.104

INTRODUCTION

The continuous growth of mobile Augmented Reality (AR) in the education field has transformed the conventional classroom environment. This innovative approach provides immersive learning content visualization that boosts the interest of students. AR has begun to show its potential as a tool to help students to learn effectively (Bistaman et al., 2018). However, review articles on the application of AR for learning biology are still rare. Thus, the main objective of this paper is to provide a more in-depth review and analyze innovative mobile apps content and design of augmented reality for learning biology.

In the next section, a brief literature review is presented. Next, we will review four articles that reported the development of mobile AR used for learning Biology. After that, three mobile applications for learning Biology that are available on Google Play will be analyzed. Lastly, the conclusion section will include the summary of the paper together with future research opportunities.

LITERATURE REVIEW

Using AR to enhance the learning process

The advancement of AR in education has provided educators and students withinnovative learning tools. It allows students to 'see' the real world. At the same time, they could view virtual scenes that are superimposed upon the physical objects of the real world. AR contents are presented in unique three-dimensional models. Engaging experiences are exposed to the students in order to help them understand abstract problems. As a result, dull facts are turned into vibrant learning experiences using marker-based AR. AR is activated by scanning the marker, defined as the trigger image. Once the device recognizes the marker, the AR content is overlaid onto the image through videos, links to websites, or 3D models (Siegle, 2019).

Meanwhile, AR technology works by creating a bridge between the real and virtual worlds. The technology removes the barriers between these two worlds by extending the physical world through added virtual layers. It works in real-time and involves interactive displays to view the augmented 3D graphics in the real world. There are several types of AR being developed. Below are the types of AR (Kiryakova et al., 2018):

- Stationary augmented reality
- Spatial augmented reality
- Desktop augmented reality
- AR using a handheld device
- Head-mounted displays

However, challenges exist in implementing AR for education. First, the students have difficulties using technology due to some interfaces that are not well-designed. This has caused the students to face a hard time while using the app. Verily, the usability of the application is vital as it affects the learning process. AR apps involve active user interaction. Therefore, the students may become frustrated and require training time to learn using the AR application. Second, AR may introduce excessive cognitive loads in the learning environment through complex learning materials, tasks, and instructions.

Advantages of AR in Science, Technology, Engineering and Mathematics (STEM)

Delivering learning contents using the chalk and talk method has been traditionally applied in the classroom setting. The learning process is dull due to the lack of engaging interaction. Conventional textbooks are packed with texts. Most of the abstract concepts are difficult to understand. These concepts are not visible before students' eyes—they are unable to visualize the concepts. As a result, they lose their focus and feel bored quickly. Biology should be one of the most interesting subjects; however, many students expressed their difficulties. Below are the reasons why Biology is considered as a tough subject (Soe, 2018):

- Most of the theories, concepts, and processes are in the abstract form.
- The chalk-and-talk teaching method used by teachers seems ineffective.
- Biology textbooks are overloaded with texts and lack of visualization.
- Memorization of Biology facts requires memorization skills and self-discipline.

According to Kiryakova et al. (2018), learners can perceive new knowledge while interacting with the AR objects when AR is integrated into STEM education. Thus, the learning process becomes more active. Today, the implementation of AR is applied in various subjects such as chemistry (Purnama et al.,

2019), physics (Fidan & Tuncel, 2019), and mathematics (Demitriadou et al., 2020). Thus, the academic community has looked into the capacity of AR to improve the learning of science subjects (Kamal & Junaini, 2019). For instance, Kurniawan et al. (2018) stated that the anatomy course is slightly difficult as a lot of memorization is required. An intensive explanation is needed from the lecturer or teacher to make the concepts clearer to students. Without AR, the students will have difficulty in understanding and applying the knowledge they acquired from the subjects.

Moreover, incorporating AR technology into education can enrich the students' learning experiences. It also increases the interest of the students in learning. AR creates an immersive and realistic experience for the students through virtual representation. Students can practice their analytical skills while observing models in AR mode. AR helps to overcome learning difficulties faced by students by concretely presenting the abstract concepts. It helps the students to visualize the content that is not visible in the real world (Erbas & Demirer, 2019). AR offers information in 3D, which allows students to have an interactive learning process. Moreover, students can better comprehend abstract concepts through the combination of AR technology and textbook (Lai et al., 2019).

Meanwhile, the advancement of mobile technology has made Mobile Augmented Reality (MAR) possible. MAR in education converts the traditional learning process into AR game-based learning by utilizing the features of mobile devices such as portability, interactivity, and connectivity. MAR has made an impact on the learning process by not only focusing on knowledge acquisition but also emphasizing learning interaction. As a result, it increases students' interest, thus provides a more meaningful learning experience. Through the object manipulation feature, the students will have a richer learning experience through an enhanced learning process.

Besides, another benefit of the implementation of AR in education is in the improvement of the students' ability to describe and practice the science analysis. Students who use AR to learn can provide a more detailed explanation about a particular subject as compared to students who only depend on the slides provided by their teachers. One of the factors that contribute to this positive effect is that students can maintain their attention and interest while observing the life-like 3D examples augmented by AR. The characteristics of the information presented in 3D promote real interaction, thus allowing the students to learn the subject at their own pace. AR 3D visualization will enable students to observe and learn about science-related objects in a detailed manner.

Besides, the implementation of AR in science may spark the curiosity of students and increase their motivation to explore deeper. Essentially, motivation is the factor that can boost the students' effort to learn and improve their academic performance. Their learning experience will become more engaging because AR can provide a visual representation, and it is a more favorable method for students with different learning abilities. Furthermore, students can receive immediate feedback when scanning through AR markers using their mobile devices.

Therefore, AR technology encourages students to have fun learning experiences, thus explore more on the subject content. Adopting AR technology in education helps to leverage the problem by presenting the information in 3D augmented content, thus reducing the cognitive load among students (Khan et al., 2019). Students can express their creativity when working on a project using AR implementation. Most AR implementation in education is marker-based as it is easy to use, user-friendly, and low in cost. The students only need to scan the markers to see the 3D augmented learning content. Various studies about the benefits of AR implementation in education are summarized in Table 1.

Table 1: Studies on the benefits of AR implementation in education

Benefits	Descriptions	Author
Presents abstract content concretely.	AR represents the abstract concepts in a clearer and tangible form.	Erbas & Demirer (2019)
Reduces textbook dependency	As the abstract concepts in the textbook are represented in a more concrete way, students will understand better.	Lai et al. (2019)
Stimulates curiosity and increase motivation among students.	Learning through AR sparks the curiosity of the students and increases their motivation to learn in a fun way.	Khan et al. (2019)
Augments the learning content.	Manipulating the 3D AR models enables the students to 'see' the hidden characteristics of the models that are usually not shown in the textbook.	G. Kiryakova et al. (2018)
Reduces cognitive load.	The plain information in the textbook is represented in less-heavy visuals, thus, reducing the cognitive load.	Garcia-Bonete et al. (2019)
Provides a visual learning method.	The visual learning method is more favorable for most students.	Karagozlu (2018)

REVIEW ON MOBILE AR FOR LEARNING BIOLOGY

APPLearn

APPLearn is an innovative mobile app developed by Ba et al. (2019) in collaboration with the textbook of Biology for the secondary schools in Singapore. It is an interactive AR tool for the students to explore the different structure of the cardiovascular system which provides a simulation of blood flows. This app aims to help students who face difficulties in understanding cardiac circulation. The challenge in learning cardiac circulation is due to the nature of its complex process.

With the development of *APPLearn*, the students can understand the cardiac circulation system in 3D. The mobile application allows dynamic interaction between the students with the 3D models of the system. Such communications enable the students to manipulate the heart model interactively. It also allows the simulation of the heart function. *APPLearn* enhances the learning process by allowing the students to learn the topics after school. They can learn at their own pace by interacting with the application. *APPLearn* has made this difficult topic become more intuitive by providing 3D visuals in a more tangible form. Fig. 1 shows the *APPLearn* application used to view the heart model in 3D.

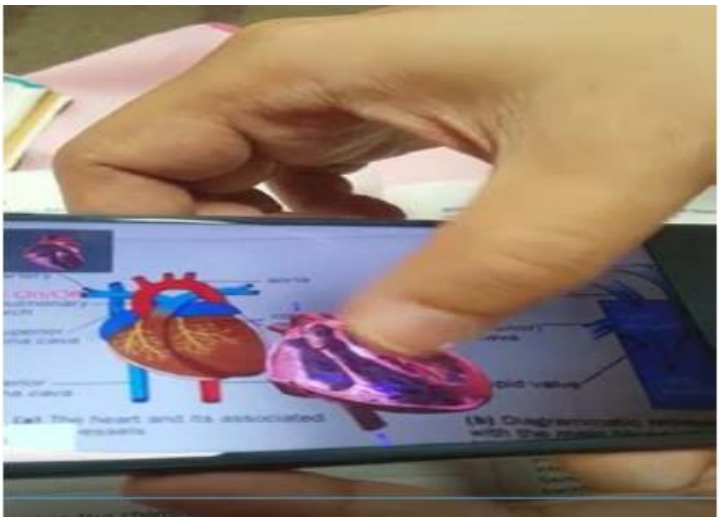

Fig. 1: APPLearn application (Ba et al., 2019)

MagicBook

MagicBook is a mobile application that is developed for medical students to learn neuroanatomy using AR technology (Küçük et al., 2016). The purpose of the *MagicBook* is to ease medical students to learn anatomy structure and provides 3D visualization for better understanding. *MagicBook* provides 3D visualization of the anatomy structure with different views and perspectives that are not available in the textbook. The conversion of static images into 3D simulation provides more depth in learning.

Hence, students can use the *MagicBook* to see multimedia materials such as 3D models of anatomy structures while reading through the textbook. Therefore, through the *MagicBook*, students can increase their academic achievement in the anatomy course. It reduces the cognitive load and presents the course more concretely. It has a positive impact on academic achievement, where AR provides immersive experiences by combining digital display with the real environment. Furthermore, AR provides flexibility for the students to learn at a pace that they are comfortable with. Fig. 2 shows the flow of using the *MagicBook* to learn the topic of neuroanatomy.

Fig. 2. The process of using the MagicBook to learn neuroanatomy (Küçük et al., 2016)

Visualization of protein data using AR

The most common method to learn the structure of proteins is using the ball-and-stick model and 3D model representation using computers. Although these tools are great to explain macromolecule proteins, they are quite tricky and time-consuming to develop. Limitations in these conventional methods have made the researchers to adopt AR as a better choice for the learning method.

Safadel & White (2018) developed an application that combines 3D modeling and AR for learning molecular biology. The 3D models of molecules are taken from the protein data bank (PDB) and are generated in the application with the integrated AR system. The users can construct and convert the complex molecule models of protein and integrate it into the AR environment. This feature enables the users to access more information and observe the characteristics of he protein model in the real world through AR. The application also allows several interaction modes such as zoom and rotate for the users to manipulate the models.

The AR aspect in the application has created an interactive learning environment, thus increasing the satisfaction level of students and allows the unseen properties to be seen by the naked eyes. Moreover, the students became more engaged in their learning activities by interacting with 3D protein models through AR which then increases their motivation to learn (Okada et al., 2018). Fig. 3 shows the visualization of the protein structure using AR.

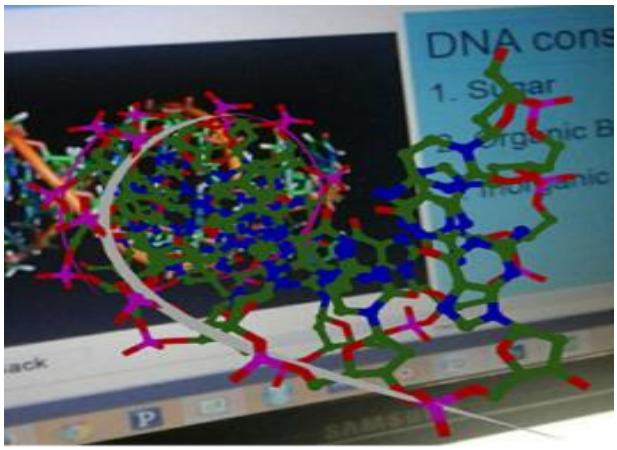

Fig. 3: 3D visualization of the protein structure using AR (Safadel & White, 2018)

HuMAR

Jamali et al., (2015) created Human Anatomy in Mobile-Augmented Reality (HuMAR). HuMAR aims to assist the students in learning the human skeletal anatomy and create a long-lasting knowledge after finishing the practical session. The application focuses on 3D visualization of selected bones inside the human body. The MAR technology helps to deliver the content effectively enhances students' motivation to learn. Learning using MAR technology has helped the students to stimulate their interest in learning human anatomy. Fig. 4 shows the HuMAR application of the skeletal bones in AR.

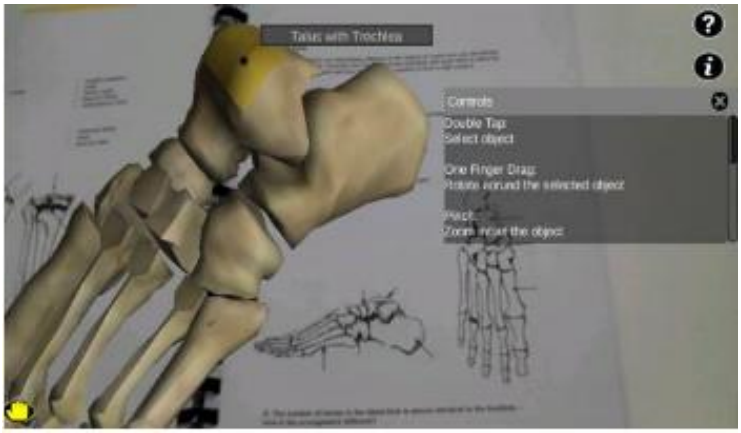

Fig. 4: HuMAR application to learn skeletal anatomy (Jamali et al., 2015)

Table 2 summarizes the review of AR for learning biology with an extended description of its effectiveness.

Table 2: Usage of AR for learning biology

Biology content	Description of the benefits		Author	
Cardiac circulation	*APPLearn* helps the students to visualize complex cardiac circulation while reading the textbook.		Ba et al. (2019)	
Internal and external organs	MAR becomes the choice for anatomy subject as it provides flexibility in viewing the human organs in AR.		Kurniawan et al. (2018)	
Protein data	The ability to construct and convert the protein molecules into 3D models makes the learning interactive.		Safadel & White (2018)	
Human body	An interactive learning environment with AR technology helps the students learn the anatomy of a human body.		Layona et al. (2018)	

RECOMMENDATION ON ANDROID-BASED AR BIOLOGY APPS

AR-3D Science

AR-3D Science (bit.ly/ar3dscience) is an innovative learning app developed by Panther Studio and released in 2017. This application is used for learning biology, chemistry, and physics using AR. In the biology section, the content consists of DNA, kidney, digestive system, respiratory system, and brain. This application uses marker-based AR to display the content. The overall rating for this application is 4.4 out of 5 stars, where the gameplay, graphics, and controls were rated 3.9 stars, 4.1 stars, and 3.8 stars, respectively, based on Play Store.

Furthermore, this application provides several features for interaction between the user and the 3D model where it allows the user to use the gesture of Pinch In-Pinch Out and rotates the 3D model on screen. Each time the application displays the 3D model, a voice-over is played simultaneously and describes the 3D model. The user interface design is simple and easy to navigate. The response time for the application to detect and scan the marker is quick. Besides that, this application can seamlessly change the 3D model based on the marker. The downside of this application is that there is no instruction on how to interact with the 3D models, as well as the absence of textual information when the voice-over is played.

AR Human Atlas

AR Human Atlas (bit.ly/arhumanatlas) is another innovative Biology app developed by 1By1Games and was released in 2018. This application focuses on the exploration of the human organ system using marker-based AR technology. This application covers knowledge about several systems of the human body, such as the skeletol and respiratory system. Each system consists of the organs that are associated with their function. This application has a rating of 4.4 out of 5 stars.

In addition, the control feature provided by the application for the user to interact with the 3D models enables the movement of the models in four directions including rotating and scaling. However, there is no main menu interface whenever the user opens the application. Users are immediately greeted with a screen to scan the marker. Also, there is a lack of description about the human organ system, including the absence of labels on the organs. This application can be used to scan the markers immediately without any problem. Fig. 5 is the screenshot of the AR Human Atlas application.

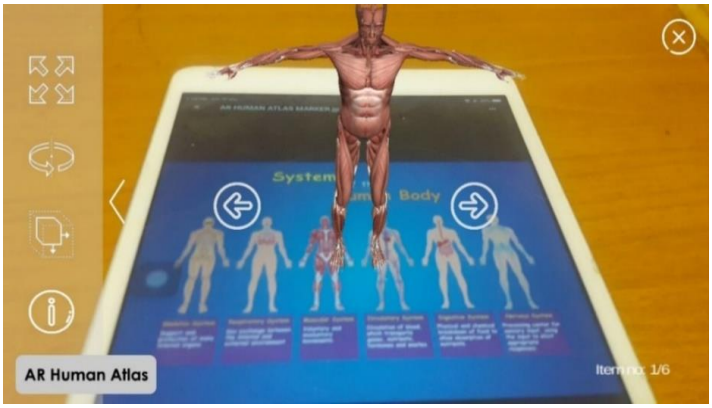

Fig. 5: 3D muscular system model with AR marker

Human Brain-Augmented Reality

Human Brain-Augmented Reality (bit.ly/humanbrainar) is another innovative app developed by Magic Software and was released in 2017. This application focuses on learning about the human brain in 3D using AR technology. The overall rating for this application is 3.1 out of 5 stars. In this application, users can deeply explore the human brain structure in 3D. This application uses marker-based technology to display the 3D brain model. Users can rotate the 3D brain model from any angles and zoom in and out of the models. Each part of the brain model are labeled clearly. The additional feature in this application enables the users to 'peel off' the layers on the 3D brain model using the slider to explore the inner parts of the brain. Fig. 6 is the screenshot of the Human Brain-Augmented Reality app.

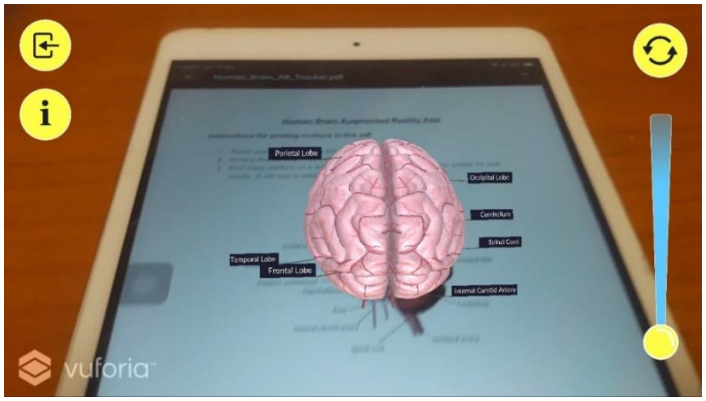

Fig. 6: Human brain 3D model with organ labels

All the AR apps are targeted for secondary school and university students and use marker-based technology. For the Human Brain-Augmented Reality app, it focuses only on the brain while the other two apps include various other human organs. Only the Human Brain-Augmented Reality app exists both on the Android and IOS platforms. Table 3 shows the comparison of properties between the three AR applications.

Table 3: General comparison of the biology apps

Criteria	AR-3D Science	AR Human Atlas	Human Brain-Augmented Reality
Anatomy parts	DNA, kidney, digestive system, respiratory system, brain	The main body system	Brain
Target users	Secondary school and university students	Secondary school and university students	Secondary school and university students
Types of AR marker	Marker-based	Marker-based	Marker-based
Platform	Android	Android	Android and iOS
Date released	2017	2018	2017
Rating on Play Store	4.4 (out of 5 stars)	4.4	3.1

For the user interface, all of the apps provide help buttons and readable fonts to guide the users. However, only the AR-3D Science app provides the main menu. In terms of navigation, all the apps provide back buttons to either undo to the previous state or go back to the main menu for the AR-3D Science app. All the apps are easy to navigate and have good usability and functionality. The Human Brain-Augmented Reality app is the only application that provides the instruction on how to scan the markers and lists out available types of interactions. The AR-3D Science app does not have recognizable action buttons on the screen.

Regarding the interaction mode, all of the apps provide the ability to zoom and rotate the 3D models. The move function is only available in the AR Human Atlas app and Human Brain-Augmented Reality app. The AR-3D Science app, however, lack this function. For the content presentation, only the AR-3D Science app provides audio features such as narration voice to describe the 3D organ models. The other two applications do not offer audio features. However, these two applications include labels on the 3D models. Table 4 summarizes the comparison on the presentation of content by the three AR applications.

Table 4: Comparison of AR content and interaction

Criteria		**AR-3D Science**	**AR Human Atlas**	**Human Brain-Augmented Reality**
User Interface	Font size	Readable	Readable	Readable
	2D button	Available	Available	Available
	Main menu	Available	Not available	Not available
	Help button	Not available	Available	Available
Navigation	Provide instruction	Not available	Not available	Available
	Back button	Available	Available	Available
	Action button (e.g., rotate, zoom, move)	Not available	Available	Available
	Ease of navigation	Easy	Easy	Easy
Interaction	Rotate	Available	Available	Available
	Zoom	Available	Available	Available
	Move	Not available	Available	Available
Content presentation	Audio (narration)	Available	Not available	Not available
	Textual information	Not available	Available	Available

For discussion purpose, five recommended design features should be considered to develop science AR apps. They include persuasive instruction, clear textual interface, predictive icons, sleek interaction, and direct navigation. Table 5 shows the detailed description of the recommendations.

Table 5: List of recommended features for developing science AR app

Features	**Recommendations**
Persuasive instruction	Specify the nature of controls that users can use with persuasive instructions on how to use the app.
Clear textual information	Provide simple but clear, and concise descriptions and labels.
Predictive icons	Design the icons that are easy to predict to represent the options for rotating, moving, and zooming the AR objects.
Sleek interaction	Implement sleek interaction to provide smooth interactivity between the user and the 3D models.
Direct navigation	Create direct and clear navigation and signposts so that the user could navigate the screen in a direct and straightforward way.

CONCLUSION AND FUTURE WORK

In conclusion, the continuous growth of innovative AR apps for science education has transformed the conventional way of learning biology. This paper has reviewed the content and design of four articles that reported the development of AR learning apps for biology. Besides, three apps for learning Biology from Google Play were reviewed and recommended. We have also discussed five innovative features for developing science AR apps. In the future, we will extend our work to also review the acceptance level of AR biology learning apps and how it impacts learning.

ACKNOWLEDGEMENT

We would like to express our appreciation to the Faculty of Computer Science and Information Technology (FCSIT), Universiti Malaysia Sarawak as well as Research, Innovation & Enterprise Centre (UNIMAS Innovation), Universiti Malaysia Sarawak for providing us with a grant to fund this research (F08/SpMYRA/1661/2018).

REFERENCES

1. Ba, R. K. T. A., Cai, Y., & Guan, Y. (2019). Augmented Reality Simulation of Cardiac Circulation Using APPLearn (Heart). *2018 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)*, 241–243. https://doi.org/10.1109/aivr.2018.00055
2. Bistaman, I. N. M., Idrus, S. Z. S., & Rashid, S. A. (2018). The Use of Augmented Reality Technology for Primary School Education in Perlis, Malaysia. *Journal of Physics: Conference Series*, *1019*(1). https://doi.org/10.1088/1742-6596/1019/1/012064
3. Demitriadou, E., Stavroulia, K.-E., & Lanitis, A. (2020). Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education. *Education*

and Information Technologies, *25*(1), 381–401. https://doi.org/10.1007/s10639-019-09973-5
4. Erbas, C., & Demirer, V. (2019). The effects of augmented reality on students' academic achievement and motivation in a biology course. *Journal of Computer Assisted Learning*, *4244*, 1–9. https://doi.org/10.1111/jcal.12350
5. Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers \& Education*, *142*, 103635.
6. Garcia-Bonete, M. J., Jensen, M., & Katona, G. (2019). A practical guide to developing virtual and augmented reality exercises for teaching structural biology. *Biochemistry and Molecular Biology Education*, *47*(1), 16–24. https://doi.org/10.1002/bmb.21188
7. Jamali, S. S., Shiratuddin, M. F., Wong, K. W., & Oskam, C. L. (2015). Utilising Mobile-Augmented Reality for Learning Human Anatomy. *Procedia - Social and Behavioral Sciences*, *197*(February), 659–668. https://doi.org/10.1016/j.sbspro.2015.07.054
8. Kamal, A. A., & Junaini, S. N. (2019). The effects of design-based learning in teaching augmented reality for pre-university students in the ict competency course. *International Journal of Scientific and Technology Research*, *8*(12), 2726–2730. http://www.ijstr.org/paper-references.php?ref=IJSTR-1219-27322
9. Karagozlu, D. (2018). Determination of the impact of augmented reality application on the success and problem-solving skills of students. *Quality and Quantity*, *52*(5), 2393–2402. https://doi.org/10.1007/s11135-017-0674-5
10. 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*, 1–14. https://doi.org/10.1155/2019/7208494
11. Kiryakova, G., Angelova, N., & Yordanova, L. (2018). The potential of augmented reality to transform education into Smart education. *TEM Journal*, *7*(3), 556–565. https://doi.org/10.18421/TEM73-11
12. Kiryakova, G., Angelova, N., & Yordanova, L. (2018). The potential of augmented reality to transform education into Smart education. *TEM Journal*, *7*(3), 556–565. https://doi.org/10.18421/TEM73-11
13. Küçük, S., Kapakin, S., & Göktaş, Y. (2016). Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load. *Anatomical Sciences Education*, *9*(5), 411–421. https://doi.org/10.1002/ase.1603
14. Kurniawan, M. H., Suharjito, Diana, & Witjaksono, G. (2018). Human Anatomy Learning Systems Using Augmented Reality on Mobile Application. *Procedia Computer Science*, *135*, 80–88. https://doi.org/10.1016/j.procs.2018.08.152
15. Lai, A. F., Chen, C. H., & Lee, G. Y. (2019). An augmented reality-based learning approach to enhancing students' science reading performances from the perspective of the cognitive load theory. *British Journal of Educational Technology*, *50*(1), 232–247. https://doi.org/10.1111/bjet.12716
16. Layona, R., Yulianto, B., & Tunardi, Y. (2018). Web based Augmented Reality for Human Body Anatomy Learning. *Procedia Computer Science*, *135*, 457–464. https://doi.org/10.1016/j.procs.2018.08.197
17. Okada, A., Pasternak Glitz Kowalski, R., Kirner, C., & Torres, P. L. (2018). Factors influencing teachers' adoption of AR inquiry games to foster skills for Responsible Research and Innovation. *Interactive Learning Environments*, *27*(3), 1–12. https://doi.org/10.1080/10494820.2018.1473257
18. Purnama, G. R. R., Hansun, S., & Kristanda, M. B. (2019). Gamified Chemistry Learning AR Application for 10th Grade Student in Indonesia. *International Journal of Recent Technology and Engineering*, *8*(2), 6100–6105. https://doi.org/10.35940/ijrte.b3853.078219
19. Safadel, P., & White, D. (2018). Facilitating Molecular Biology Teaching by Using Augmented Reality (AR) and Protein Data Bank (PDB). *TechTrends*, *63*(2), 188–193. https://doi.org/10.1007/s11528-018-0343-0
20. Siegle, D. (2019). Seeing Is Believing: Using Virtual and Augmented Reality to Enhance Student Learning. *Gifted Child Today*, *42*(1), 46–52. https://doi.org/10.1177/1076217518804854
21. Soe, H. Y. (2018). A study on high school students ' perceptions toward biology learning (Myanmar). *International Journal of Applied Research*, *4*(9), 248–251.