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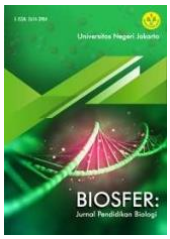

Augmented reality (AR) technology on the android operating system in human respiratory system: From organ to cell

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ABSTRACT

Understanding the object of learning material that is abstract is currently still an obstacle faced by students. The use of technology in learning is expected to reduce the obstacles faced by these students. Augmented reality (AR) is a technology that is currently being widely applied in the learning process because it is considered capable of helping students understand abstract learning materials with 3D object features. This study aims to design and develop AR, especially in the anatomical structure of organs in the human respiratory system, which is then integrated into biological practice in the laboratory. The AR application has been designed, created, validated, and published under AR Synapse (Augmented Reality Respiratory System). The AR application developed is based on the android system and has gone through validation tests by experts. Five expert validators who work as lecturers and high school teachers. Expert validation results with an average score of 3.6 from a maximum score of 4.0, which states that the AR Sinaps application is 91.2%, has functioned well, supports learning, provides objects relevant to teaching materials, and is considered to increase students' learning motivation. Furthermore, it has good prospects for continuous development. Students' satisfaction survey and user evaluation also gave a good response with an average rating percentage of 85.1%.

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INTRODUCTION

Biology is a scientific discipline with a complex scope and discussion about all living things in nature (Celik, Guven, & Cakir, 2020; Doğan, & Ay, 2013). This fact then makes it difficult for most teachers to design a learning activity that helps students' understanding of biology material (Akpınar, 2006; Celik et al., 2020; Kılıç & Sağlam, 2004). Errors in designing learning activities can impact creating a learning climate that is not conducive, making it difficult for students to understand the material presented and decreasing student motivation. So it is not uncommon for students to feel uncomfortable when studying biology (Kaya et al., 2015).

Innovative technology in learning can enrich the learning process, especially when explaining invisible biological objects such as cells, DNA, and tissue structures or knowing biological processes in the body that are difficult to observe directly. Currently, many technologies are used to help the learning process both online and offline, such as animation, simulation, coding robots, mobile learning, holograms, podcasts (digital storytelling), and digital games. (Günüç, 2017; Johnson, 2015). Augmented reality (AR), which has been around since the 90s, has become a technological innovation product that continues to develop in the learning process.

Augmented reality (AR) is a technology that can provide 2D and 3D depictions of an object. Mobile augmented reality is AR that can be accessed using a smartphone (mobile device). AR in biology learning can make it easier for students to understand the material that is abstract and difficult to observe. Augmented reality is a technology that can improve the user's perception and interaction with the natural world (Azuma, 1999; Thomas, 2007). Augmented reality has three characteristics: combining virtual content with real content, having an interactive system that can be used in real-time, and virtual content being added to the real world. In several previous studies, AR is a technology that can be applied broadly, including Education, Health, Engineering, Military, and Entertainment (Thomas, 2007).

AR technology in teaching and Education has been widely developed in developed countries. AR collaboration in learning mathematics and geometry by making Construct3D improve students' spatial thinking skills in Austria (Kaufmann, 2003). AR has also been developed in science learning in order to improve understanding through visualization of 3D objects (Hurst, 2020) in the field of chemistry for the introduction of chemical sources (Nechypurenko, Starova, Selivanova, Tomilina, & Uchitel, 2018) and in biology learning in Malaysia with the development of the ATTech System (Weng, Bee, Yew, & Hsia, 2017).

The advantages of using Augmented reality in learning can be divided into three categories, namely in terms of learning outcomes, pedagogical contributions, and interactions. AR can increase students' positive behavior towards learning activities, improve learning achievement, and learning performance and can increase student satisfaction with the learning process (Akçayır & Akçayır, 2017; Chen & Tsai, 2012; Chiang, Yang, & Hwang, 2014; Lu & Liu, 2015; Muñoz-Cristóbal et al., 2015). AR contributes to increasing student engagement and engagement in the learning process and makes learning more fun (Akçayır & Akçayır, 2017; Lu & Liu, 2015).

AR technology in the learning process is proven to increase motivation and assist students in observing material learning objects that are difficult to see by the eye (Akçayır & Akçayır, 2017; Wu, Lee, Chang, & Liang, 2013). Biology learning full of microscopic objects can be easily visualized in 2D and 3D through AR. The understanding of organ anatomy in the laboratory by students and prospective teacher students can be facilitated by 3D visualization of organs through AR. Especially during the pandemic with online learning or blended learning, AR as a learning medium is believed to increase students' and students' understanding of the material provided.

AR in learning has been shown to affect learning outcomes such as learning outcomes, motivation, and student attitudes. The mobile AR approach can improve students' learning performance (Chiang et al., 2014). Spatial concepts and sustainability of multimedia with good integration and arrangement, relevant material can help students explore their cognitive abilities (Mayer, 2009). Other categories of learning outcomes such as satisfaction and self-confidence have not been investigated much, although they also have an essential role in the world of Education.

In pedagogy, the use of AR contributes to increased enjoyment of learning (enjoyment) and increases student involvement in learning activities. AR can make boring learning entertaining (Lu & Liu, 2015). The implementation of AR coupled with a game-based learning approach makes the learning process fun. It makes students more voluntary to engage in learning activities and give their best performance. (Chen & Tsai, 2012). AR can also facilitate hybrid/blended learning because it can combine digital environments with natural physical objects. The use of AR also provides advantages for increasing interaction between students, and also the interaction between teachers and students (Akçayır & Akçayır, 2017). In other studies, AR has proven to be very useful in helping students with visual learning styles because it helps them visualize abstract concepts or phenomena that are difficult to observe. (Wu et al., 2013).

However, the use of AR is also inseparable from several weaknesses. AR technology can be very complicated to use without good design, programming, and students' explanation (Squire & Jan, 2007). This technology must be made smaller, lighter, easy to carry and accessible anywhere, and fast graphic design. However, despite these weaknesses, the use of AR has far more advantages and is effectively used in the world of Education.

Recent studies on AR state that this technology can improve laboratory skills in students and build good behavior (attitude) in working in the laboratory (Akçayır, Akçayır, Pektaş, & Ocak, 2016). The implementation of AR in learning is mainly done at the secondary education level (51%) and higher Education (29%); this is

presumably because AR technology is suitable for increasing the involvement of young students in learning (Lee, 2012). AR technology as a learning medium has begun to be made by prospective teacher students, especially in the Biology Education Study Program, Universitas Negeri Jakarta. Previous research conducted by a research team from the Biology Education study program at the Universitas Negeri Jakarta, Indonesia regarding the development of augmented reality-based AR-SENSE applications has been shown to increase mastery of the concept of the human sense system at the high school level. (Qarnain, 2020). Other research on the digitalization of the world of Education using augmented reality technology in mathematics learning has shown that AR technology can increase interest, motivation, and outcomes of a learning process. (Khairunnisa & Aziz, 2021).

Based on the previous research mentioned above, research and development on AR learning media continue to be developed, especially at the Universitas Negeri Jakarta for various fields of science. In order to provide a better learning process for students and contribute to the community, in this case, if teachers and students in high school use it. The creation of AR as a learning medium and its integration in learning activities needs to be developed sustainably following current technological developments to improve students' understanding and academic performance and prospective teacher students in online or offline learning. The development of AR technology-based learning media can be accessed anywhere and anytime can help students understand abstract objects through 3D visualization. Planting the concept of the hierarchy of life in biological material will significantly assist students in understanding the following complex materials. The depiction of the hierarchy of life from organs to cells also shows the function of each part of its constituent structure, sometimes very hard to understand. It will be effortless if assisted with 3D objects such as AR technology.

Thus, this study aims to design and develop AR as a learning medium to describe the hierarchy of the organization of life from organs to cells. With this concept, students can see an accurate visualization that the organs in the human body are composed of tissues with unique structures. The tissue structure in each organ plays a role in the bioprocesses in these organs. According to O'Shea, augmented reality technology can make a person perform real interactions in the world or things that are impossible to do. (O'Shea, 2011). Bajura, Fuchs, & Ohbuchi, (1992), in his research, developed a medical interface that displays an ultrasound image of the patient's body; this makes it easier for doctors to see the location of the X-rays exposed during a biopsy. (Bajura, Fuchs, & Ohbuchi, 1992). The respiratory system material was chosen because of the research limitations in terms of making 3D objects. This research has not made many 3D objects, and the respiratory system is the organ system with the least number of organs. Therefore, the respiratory system was chosen as the material for making this AR learning media. The results of this study are expected to improve the understanding and academic performance of prospective Biology Education teacher students, both in offline and online learning.

METHODS

Research Design

This study uses research and development methods to produce a product that will then be tested for quality. Development research in Education is used to develop and validate Educational products (Bennett, Borg, & Gall, 1984). The stages of development research by Borg and Gall include ten steps. Research the research stages are grouped into three major stages, carried out for two years. The first year focuses on the first stage, namely a preliminary study or (1) research and information collecting, and the second stage is the media development stage which consists of eight activities, namely (2) planning, (3) developing a preliminary form of product, (4) preliminary field testing, (5) primary product revision, (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision. The effectiveness test and dissemination phase will be carried out in the second year of research. This first-year research was conducted in 2021 at the Biology Education Study Program, Universitas Negeri Jakarta, Indonesia.

Population and Samples

The subjects of this research and development include three validators who are material and media experts, who validate and assess the resulting product. Expert validators consist of two categories: lecturers who are experts in the field of digital media in learning and high school biology teachers who use digital media to implement learning. The user satisfaction survey is aimed at first-level students of Biology Education at the Universitas Negeri Jakarta with moderate criteria and having taken general biology courses. The number of samples at the small-scale field trial stage was 30 students. The research was conducted from February to September 2021.

Instrument

The instruments used for data collection include product validation instruments in terms of material and media with a total of 14 points for assessment indicators for media assessment and 20 items for the content assessment using a Likert scale of 1-4 (Strongly disagree - Strongly Agree). Another instrument used is the application testing instrument (User Acceptance Test) to test the operational process of the developed application. The last instrument used is an evaluation instrument for the use of applications by users with 32 assessment indicators using a Likert scale of 1-4 (strongly disagree - strongly agree). Item statements of expert validation instruments and evaluation of application usage are developed based on field test indicators for applications covering aspects of implementability, sustainability, appropriateness, acceptance and attractiveness, and

effectiveness (Zulfiani, Susanti, & Qumillaila, 2017). The instrument has gone through a process of validation and reliability testing.

Procedure

Based on the research design and development of Borg & Gall, a modified research phase will be carried out according to research needs. The research design and development stages of Borg & Gall have ten stages starting from information gathering to the dissemination and implementation stage. This study has not carried out the large-scale field test stage and the effectiveness test stage (dissemination) due to limited research time. The field test conducted in this study was still a small-scale test, which was only in one class at the Biology Education Study Program, Universitas Negeri Jakarta. The stages of the research can be seen in the following flow chart in Figure 1.

Figure 1. Research Plan

Data Analysis Techniques

The data will be taken in the form of expert validation results and satisfaction surveys (suggestions and inputs) from the use of the product by the sample students. The data obtained will be analyzed descriptively quantitatively. Expert validation data was obtained using a product assessment instrument. Satisfaction survey data from product use were obtained using a product use evaluation questionnaire.

RESULTS AND DISCUSSION

Application Development of Augmented Reality Respiratory System (ARSINAPS) based on android

Developing an augmented reality application based on the android system begins with observing material needs. Based on the observations, the complexity of the material, and the time of the study, the respiratory system was chosen as the material to be developed for an augmented reality application based on the android system. After determining the material, the module began to be compiled with material adapted to be used by students at the high school level and students in the first year of biology education. The focus of the material compiled in Augmented Reality (AR) modules and applications that will be made is about the structure of the organs in the respiratory system. This material is chosen because students' understanding of the tissue structure and the relation with the function of the organs is relatively low due to its abstract nature and difficulty visualizing. So, AR applications with 3D objects are expected to provide a better picture and visualization to help students understand the structure of the tissues that make up organs. After the module and the initial design of the object are created, the application development process begins. This application is named AR SINAPS from Augmented Reality Breathing System. The application development process has ten stages which can be seen in Figure 2.

The process begins with creating a three-dimensional object based on a sketch or object design that has been created using the Blender application. The Blender application used is Blender ver 2.9. After the object creation is complete, proceed with coloring and naming the object according to the design. The creation of objects in the AR SINAPS application includes objects of alveoli, respiratory bronchioles, ciliated pseudo-stratified epithelium, simple cuboidal epithelium, pseudo-coated cuboidal epithelium, longitudinal section (longitudinal section) of the trachea, the cross-section of the trachea, capillaries, and trachea. After creating the object, go to the second stage to change the object format, which previously had the .blend format from the blender application to fbx. This step is done so that objects can be used in UNITY applications. UNITY is a platform used to create 3D objects created in stage one that can be used on the android system. After the second step, objects in .fbx format are imported into UNITY and materials (colors) that match the objects.

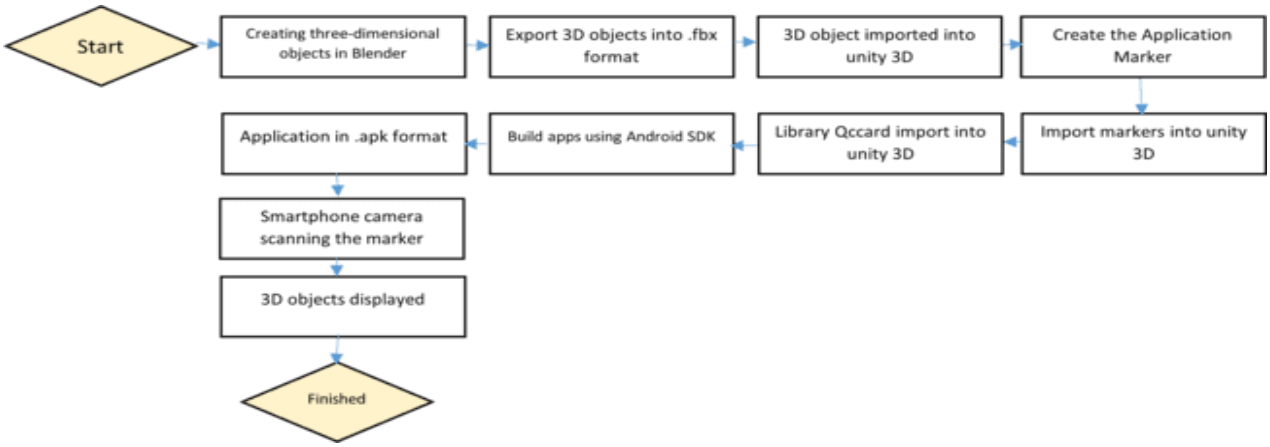


Figure 2. Application development design flowchart

The following process is to make a marker. Marker is an image that will be attached in a digital/print module to be scanned to display the 3D object that has been created. The markers made in this application can be seen in Figure 3. Users who have installed the application on their cellphones can directly scan in Figure 3 to see 3D objects from the augmented reality media that has been developed.

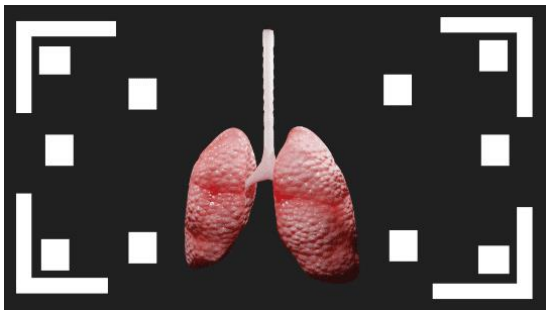


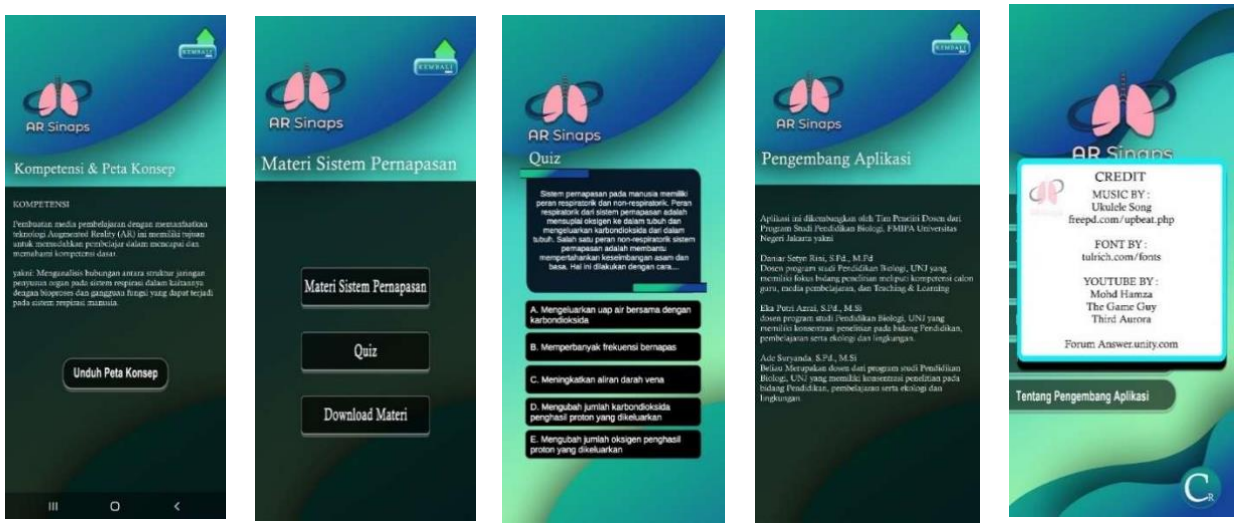
Figure 3. AR SINAPS Application Marker

After the marker is created, the marker will be entered into UNITY. Importing markers into UNITY uses a package from a third party, namely Easy AR. This application is used to be a package that can be used for making augmented reality-based applications. After the import marker stage, the following process builds the application using the SDK. In this process, the application will be built to proceed to the following process, namely changing the application format to .apk. The .apk format is a standard format that can be read by the Android system so that applications can later be installed and run on the system.

After the application has been converted into .apk format, the application can be run on the Android system after going through the installation process. The application can already be used after the application is installed on a cell phone that uses the Android system. The object can be raised by scanning a previously made marker using a cell phone camera. After the marker image is scanned, the 3D object will appear according to the design designed at the beginning of the application. The following is a display of the user interface of the AR SINAPS application can be seen in Figure 4.

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

Figure 4. AR Sinaps Application' All User Interface (1), (a) application icon display on the mobile menu layer, (b) main menu display of the application, (c) application user manual page display, (d) application page display.



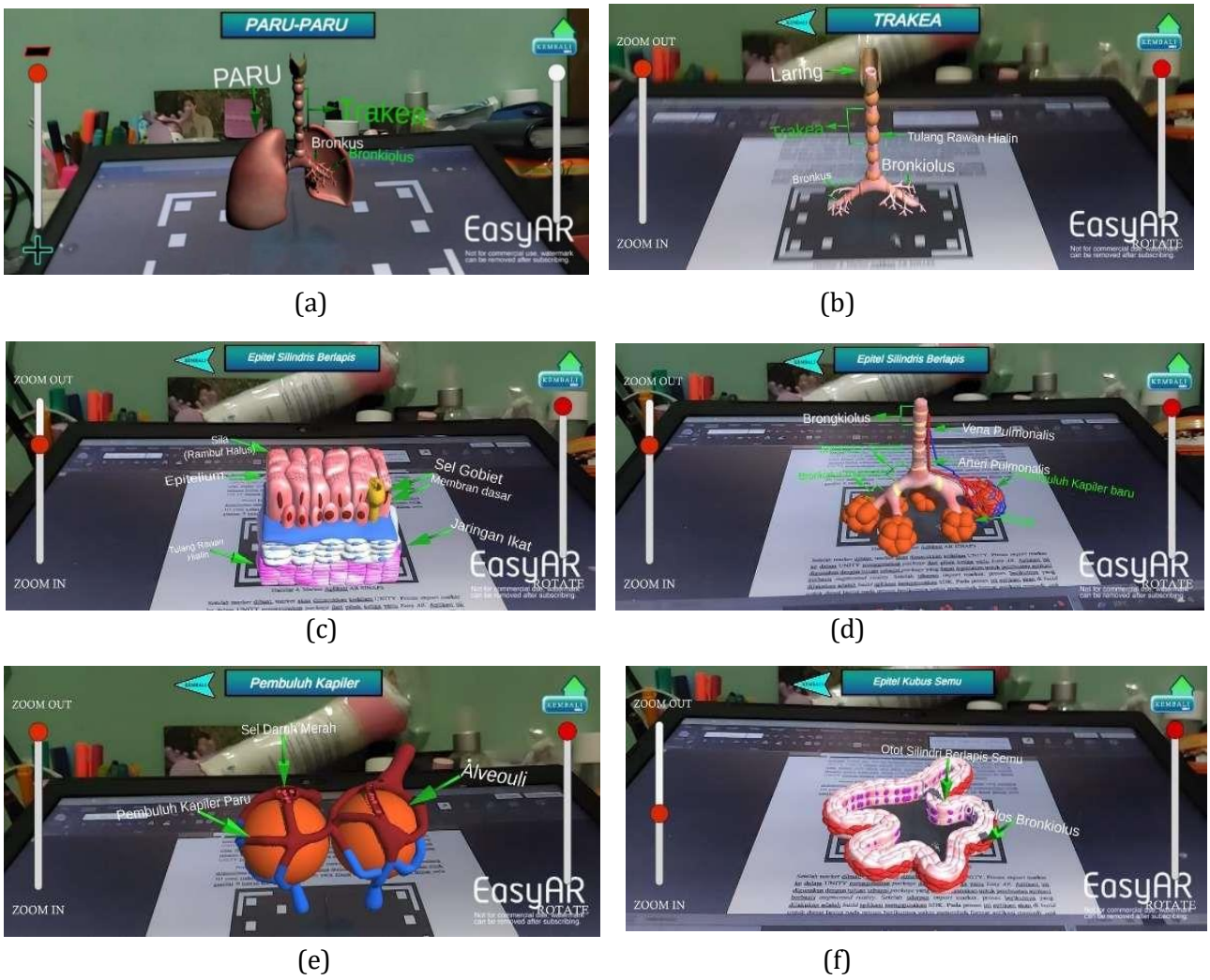
(a) (b) (c) (d) (e)

Figure 5. AR Sinaps Application' All User Interface (2), (a) display of competency pages and concept maps of the material on the application, (b) display of the start page to access 3D objects from the material, download material modules and access the material evaluation quiz, (c) quiz page (evaluation) of the material on the application, (d) page regarding application developer information, (e) credit page of the application.

The application consists of six main menus: instructions for using the application, about applications, competencies and concept maps, respiratory system materials, application markers, and application developers. 3D objects can be displayed through the respiratory system material menu. The module can also be downloaded in this menu. The appearance of the 3D object can be seen in Figure 6.

Product Validation Test

The next stage of research carried out after the application has been developed and made is the validation test. In this study, the product has gone through a validation process by three media and material experts and two teachers as users later at the high school level. Overall, the five validators agree that the AR SINAPS application product is excellent, with an average rating for each aspect item assessed in the range of 3.5 - 4. The details for each aspect of the assessment can be seen in Figure 7.



(a) (b)

(c) (d)

(e) (f)

Figure 6. (a) Lung Organ Object**,** (b) Respiratory tract 3D objects**,** (C) the 3D object of respiratory tract tissue structure**,** (d) the 3D object of respiratory tract and alveolus**,** (e) 3D object magnification of the alveoli and surrounding capillaries**,** (f) 3D object the structure of the bronchioles making up the tissue

Based on the validation results Figure 7, it can be seen that the aspects of the media interface and function that assess the features, appearance, implement ability, and function of the application get a score of 3.5 out of 4.0. In this case, the validator states that 87.1% application has been running well. There were no errors during testing, 3D objects can appear as expected and function properly, the user interface provided is also good, contrasts, and can be read clearly. The second assessment criteria regarding learning support capacity and object relevance, the validator also gives a score of 3.5 out of 4.0, which states that the application has 87.1% succeeded in displaying correct and relevant 3D objects according to the learning material being developed. It is just that because of the limitations of the use of technology, the 3D image display still does not look very similar to the original object of the organ. However, the 3D objects displayed have been able to assist students in providing correct visualization of the organs and tissues in question.

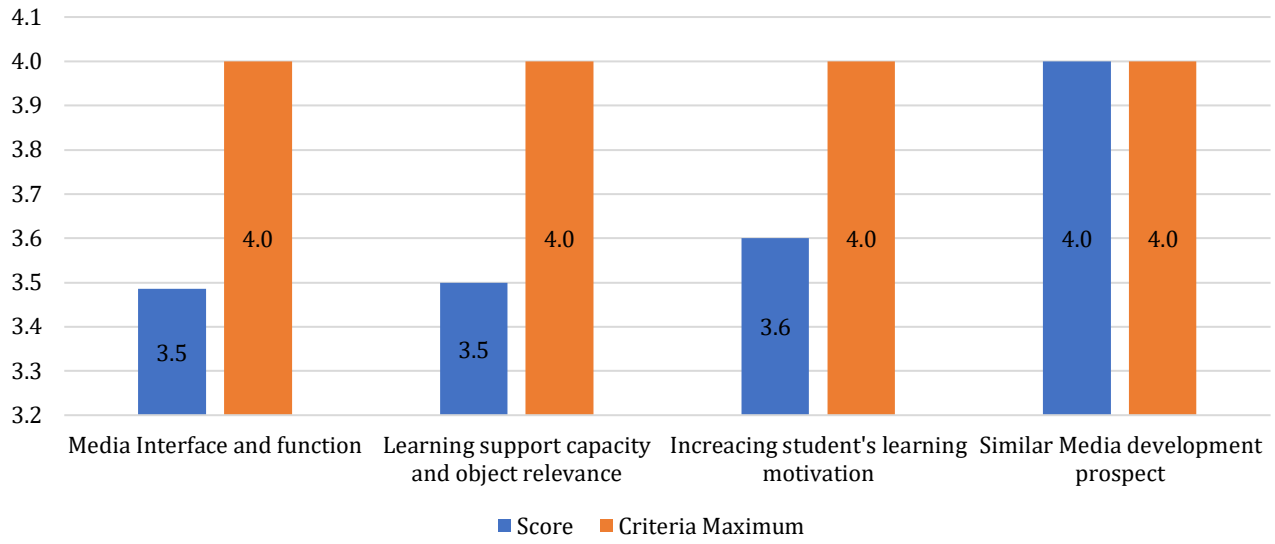


Figure 7. Expert Validation Assessment Result

In this aspect, the validator also assesses that the application can be used as a learning medium that supports student learning activities and helps students' understanding in learning. This result is in line with Hurst's research, which states that AR is developed in science learning to improve understanding through the visualization of 3D objects (Hurst, 2020). The following assessment criteria regarding increasing student motivation in learning, the validator assesses the AR application can increase students' learning motivation. The advantage of AR, which has 3D object visualization technology can provide a new learning experience for students. This new learning experience can attract students' attention and increase students' active involvement in learning, increasing student motivation. This result is in line with previous research which states that AR can increase students' positive behavior towards learning activities, improve learning achievement, and learning performance and can increase student satisfaction with the learning process (Akçayır & Akçayır, 2017; Chen, & Tsai, 2012; Chiang, Yang, & Hwang, 2014; Lu, & Liu, 2015; Munoz-Cristobal, Jorrin-Abellan, Asensio-Perez, Martinez-Mones & Prieto, & Dimitriadis, 2015).

3D objects are also fascinating. The AR Sinaps application features that can explore parts of organs to tissue forms, to cells can provide exciting and fun learning. Students also look so enthusiastic during learning when using AR media. In previous research, it was stated that AR contributed to increasing student engagement and engagement in the learning process and making learning more fun (Akçayır & Akçayır, 2017; Lu, & Liu, 2015). AR technology in the learning process is proven to increase motivation and assist students in observing material learning objects that are difficult to see by the eye (Akçayır & Akçayır, 2017; Wu, Lee, Chang, & Liang, 2013)

The final assessment aspect by the validator is the prospects for developing the AR Sinaps application in the future. The validator gives a score of 4.0 out of a maximum score of 4.0. This result states that the AR Sinaps application is believed to have good development prospects in the future. We are seeing the continued development of technology in learning today and the digitalization process of Education today. The use of digital and mobile-based learning media is predicted to experience rapid development. Thus, it is better to continue to develop AR-based applications. Moreover, the demand to provide a fun learning process will increase so that AR-based applications can provide a pleasant learning experience to students both at the high school level or at the college level.

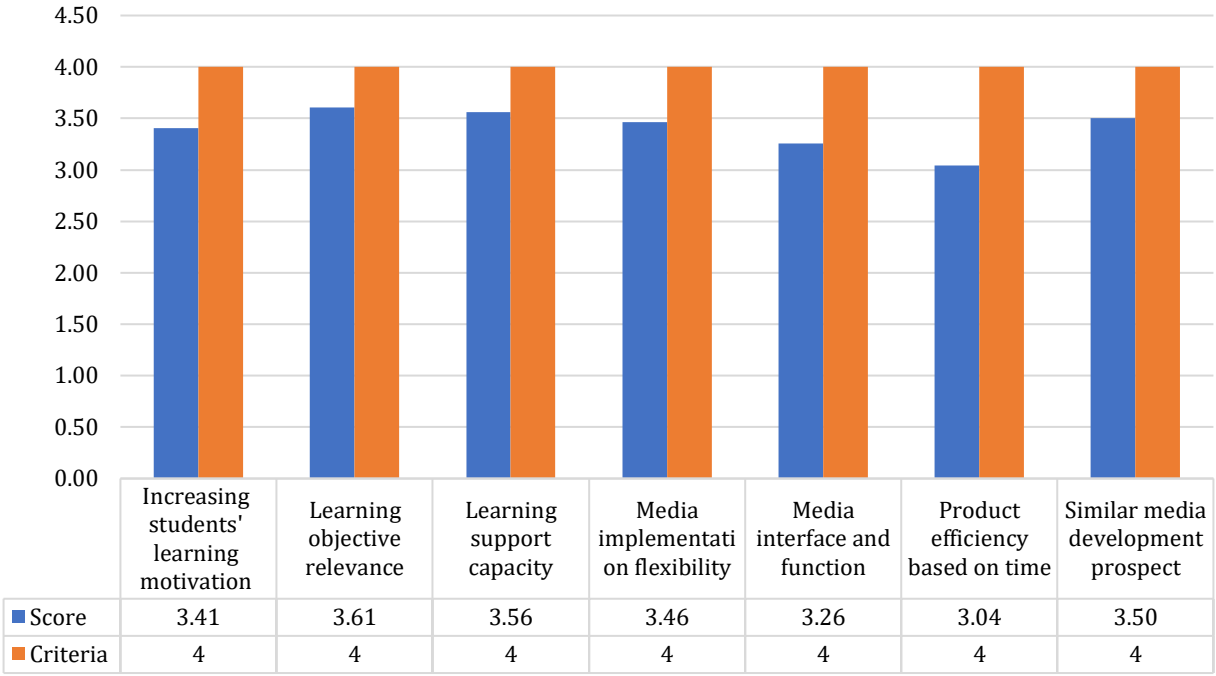
AR provides a fun learning process. This state is in line with previous research or the theory that AR contributes to increased enjoyment of learning (enjoyment) and increases student involvement in learning activities because AR can make boring learning more entertaining (Lu, & Liu, 2015). The implementation of AR coupled with a game-based learning approach makes the learning process fun. It makes students more voluntary to engage in learning activities and give their best performance. (Chen, & Tsai, 2012). AR can also facilitate hybrid/blended learning because it can combine digital environments with real physical objects. The use of AR also provides advantages for increasing interaction between students, and the interaction between teachers and students (Akçayır & Akçayır, 2017).

App Usage Evaluation

The application product developed after going through the internal validation stage by the research team and external validation by experts has been tried to be used in the learning process of general biology practicum courses at the Biology Education Study Program, Jakarta State University in the Class of 2021. Students involved in small-scale trials as many as 28 people. 10.7% male students, 89.3% female students with an age range of 17-20 years. As many as 37% of students have heard of Augmented reality, 44.4% have never heard of augmented

reality, while another 18.5% stated that they may have heard of AR applications. Another survey stated that 77.8% of students had never operated an Android-based AR application and the remaining 22.2% stated that they had operated an AR application.

The survey regarding the evaluation of the use of applications integrated into practical learning uses an instrument with 29 points of assessment. The results of the evaluation of application use can be seen in the following graphic image (Figure 8),



	Increasing students' learning motivation	Learning objective relevance	Learning support capacity	Media implementation flexibility	Media interface and function	Product efficiency based on time	Similar media development prospect
Score	3.41	3.61	3.56	3.46	3.26	3.04	3.50
Criteria	4	4	4	4	4	4	4

Figure 8. Results of the Evaluation Survey on Application Use by Students

Based on the evaluation survey results on the use of the application, the responses and assessments given by students after using the AR Sinaps application in general biology practicum learning were excellent. Overall, students do not experience difficulties when using the application. This result may be in line with research conducted by Lee, which states that AR is suitable for increasing the involvement of young students in learning (Lee, 2012). Based on the data obtained, the score for each criterion is in the range of 3.4 - 4.0. This data means that students as users assess the AR Sinaps application as having good and attractive features, easy to operate anywhere and anytime, and is considered to help understand and visualize learning mate, make learning more fun, and increase enthusiasm and enthusiasm.

Using this application makes students more interactive and actively involved in the learning process. In the current pandemic conditions that require much independent learning, students find it very helpful to understand the material provided by the visualization of 3D objects. According to research results, AR can facilitate hybrid/ blended learning because it can combine the digital environment with real physical objects. The use of AR also provides advantages for increasing interaction between students, and the interaction between teachers and students (Akçayır & Akçayır, 2017).

Students also state their willingness to use this and other similar applications in lecture activities. The 3D object feature of augmented reality makes the learning process more interactive and exciting, facilitating understanding. Errors are also sporadic when using the application. Based on the survey results, the most exciting thing from the AR Synapse application is 3D objects and markers become 3D images. The AR Sinaps application has been published on the google play store since September 2021. The application has been installed on more than 50 devices with a rating of five (ratings range 1-5). The responses and comments given by the users are also excellent and based on the monitoring of application activity. There were no errors, crashes, or other system problems during the trial period. So, this application is considered ready for use on a larger scale.

The applications developed in this research still need to be better. Applications that have been developed at this time are still limited to bringing up a description of the function of each part of the organ's structure. The temporary solution that has been done is to provide additional features and learning videos that can be accessed through the module. The zoom-in feature is also limited by clicking on the text of the part that wants to enlarge. It will continue to be developed so that the zoom-in feature can be used more realistically so that users feel like they are entering the organ. This zoom-in feature technology needs to be supported using adequate hardware.

CONCLUSION

Augmented Reality applications for respiratory students based on the android system have been successful. The AR Sinaps can be appropriately operated on the android system and plays a role in providing a better visualization effect on observing the tissue structure of the organs that make up the respiratory system in humans. The product has gone through three validation processes by material and media experts, two teachers, and students as users. The validation test results from five validators stated that the 91.2% application had functioned well, supported learning, provided relevant objects, and was judged to increase students' learning motivation. Students' satisfaction survey and user evaluation also gave a good response with an assessment value range of 3.4-4.0 from a maximum score of 4.0.

AR Sinaps applications still need to go through the large-scale field and effectiveness testing to improve performance. Based on the assessments of validators and users, the AR Synapse application has good prospects to continue developing not only in one teaching material but also in other teaching materials. The development of learning media with augmented reality technology certainly contributes to the progress of the learning process, especially in learning science and biology. Students can more easily understand the material with authentic depictions of abstract objects and cannot always be observed in their original daily form. Integrating technology with practicum activities is also very helpful, especially for observing and working on dangerous practicum activities.

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