RESEARCH ARTICLE

Virtual tour based in augmented reality as a biology learning media

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Abstract: This study aims to see the validity and practicality of augmented reality-based virtual tour biology learning media. Media was developed specifically for the introduction of cell organelles. This research applies Research and Development research and uses the Interactive Multimedia System Design and Development method as the system development method. The steps for developing IMSDD are system requirements, design considerations, implementation and evaluation. The research was conducted at MAN Palopo with research subjects of eleventh class of math and science with 24 students in total. Data collection techniques include observation, interviews and questionnaires using interview guide instruments, observation sheets and questionnaire sheets. Data analysis techniques are carried out qualitatively and quantitatively. The research results (1) The validity of media after going through the validation test stage by the two experts, namely 96.16% is in the valid category, (2) The results of the practicality test by students obtained results of 87.83% in the very practical category, while the results of the practicality test by the teacher obtained a result of 96% in the very practical category. The presence of augmented reality-based virtual tour media in the introduction of cell organelle material is able to facilitate students in recognizing each microscopic cell organelle so that it appears real. The use of Augmented Reality based virtual tours in learning allows students to learn independently outside the classroom and can increase the learning experience to be more interactive and interesting for students.

Keywords: augmented-reality; biology learning media; cell organelles; IMSDD model; virtual tour

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Introduction

The development of science and technology is increasingly rapid, forcing people from all over the world to follow the flow of change (Buheji & Ahmed, 2020). Changes occur in all sectors of life, including in the world of education. The presence of the industrial revolution 4.0 increasingly threatens the existence of various types of professions, including the teaching profession (Ghufron, 2018). A teacher must be equipped with adequate digital literacy skills in the era of society 5.0 to survive the era of shift from millennial to zoomers (Arifah et al., 2021; Sugiarto & Farid, 2023). Generation Z has characteristics that are very different from previous generations, namely they are very closely related to the use of the internet and gadgets (Hastini et al., 2020). The use of technology in learning activities will provide an academic nuance that is in accordance with the needs and development of students. Diverse learning resources will enrich students' knowledge (Ratminingsih & Subiantoro, 2023).

Technological developments require innovation such as increasing the ability to design learning media that are in accordance with the characteristics of students (Kusumaningtyas et al., 2020). One solution offered through the development of learning media that is easily accepted by students is material that can be accessed via Android-based devices (Churiyah et al., 2020). Some Android-based learning media such as Augmented Reality-based learning media (Nasongkhla et al., 2019; Zhang, 2021), the use of the Adobe Flash CS 6 application (Adesti & Nurkholimah, 2020), the use of the *Appy Pie* application (Astuti et al., 2018; Rivai et al., 2021; Widyaningrum et al., 2022).

One of the materials in biology subjects that is considered complicated by students is the material about cells (Mellisa & Ifatrizah, 2022). Students still have difficulty in distinguishing various forms of cell organelles because of their microscopic size so that they cannot be seen with the naked eye (Agustin & Wardhani, 2023). Tracing cell organelles are identical to the use of a microscope (Norregaard et al., 2017). However, the expected results are not optimal because the light microscope has limited

magnification so that the images or shapes obtained are less than optimal, various technical obstacles originating from students cause failure in observations, and the observation results obtained by each group are different so that it is necessary to find reference images to see various images of cell organelles that are expected to align perceptions about the forms of cell organelles. Learning about cell material certainly requires more complex media, so that students will get more real forms of cell organelles for example augmented reality (Roeder et al., 2022).

One study shows that the use of augmented reality-based media can have an impact on students' high-level thinking skills (Demircioglu et al., 2022; Sylvia et al., 2020), it is in accordance with the demands of 21st Century learning. Furthermore, researchers also found one of the products of digital technology developments that can be used to explore an environment at a time, namely virtual tour. Hikmawan and Sofiani (2021) showed that learning runs smoothly by following the syntax of a virtual tour assisted by handouts, which can indirectly encourage students to reconstruct an event through the video display available on their gadgets. The results of previous research on virtual tour application as a web-based campus environment introduction media found that the application developed can run according to its function and can be used by students to get to know the campus environment (Dianta et al., 2021). Virtual tour research is mostly used in the tourism sector such as museums and tourist destinations (Bretos et al., 2024; Wibowo et al., 2020).

However, virtual tour on learning discovery is still limited. This research will make a new discovery on a cell object into the virtual tour. The research gap is that there is no research that specifically utilizes virtual tour to introduce and explain the structure and function of cells as complex biological objects. This research aims to integrating augmented reality technology into virtual tours, especially on the material on introducing cell organelles to show all the organelles found in cells, both in animal cells and plant cells.

Method

This study applies the type of Research and Development (R&D) research and uses the Interactive Multimedia System Design and Development (IMSDD) method as a system development method (Dastbaz, 2002). IMSDD is a method that has a goal in the design and development stages used in interactive multimedia systems. IMSDD focuses on a structured and organized design approach (Khairunnissa et al., 2020). The IMSDD method provides a systematic approach in designing and developing technology-based learning media. The steps for developing IMSDD can be seen in Figure 1.

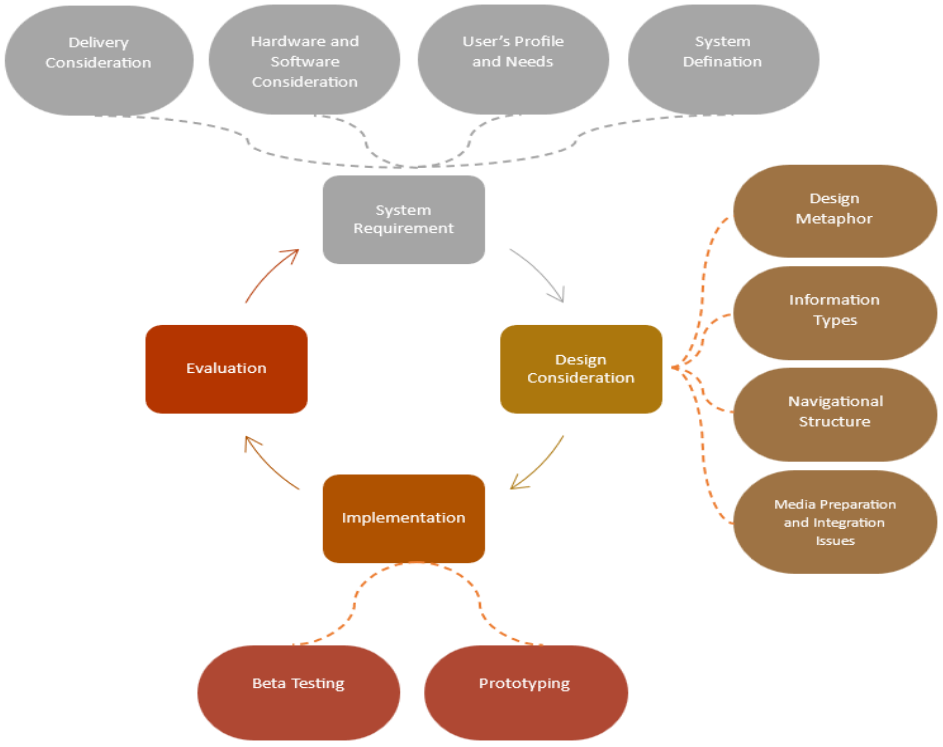

Figure 1. Design metaphors for each scene

The advantage of the IMSDD method, namely virtual tour based on augmented reality as a biology learning medium, will not only produce innovative and interactive media, but will also increase the

effectiveness and quality of student learning, especially in understanding complex biological material such as the structure and function of cells.The description of each step of IMSDD development carried out is as follows.

a. System requirements. The first stage in IMSDD is (1) defining the system in general, (2) clarifying each user who will use the system, (3) evaluating each hardware and software requirement that will be used, (4) considering the technology or delivery media that will be used in the system to be created.
b. Design consideration. The second stage is to describe clearly and in detail the design of the media to be created through the user interface design.
c. Implementation. The third stage of IMSDD is to create a media prototype and test the prototype that has been created.
d. Evaluation. The last stage of IMSDD is to evaluate the media according to the purpose of developing the media (Dastbaz, 2002)

This research was conducted at the State Islamic Senior High School (MAN) Palopo, Palopo City, and South Sulawesi. The subjects of the study were 24 students of eleventh math and science class. The object of the study was virtual tour learning media based on augmented reality. The research was carried out for a semester.

Data collection techniques were in the form of observation, interviews and questionnaires using interview guide instruments, observation sheets and questionnaire sheets. The validity of the media developed can be seen based on the validation results by the two experts, namely media experts and material experts. Validation by more than one expert provides higher objectivity in assessing the quality and suitability of the AR media being developed. Each validation questionnaire has different aspects. Each aspect assessed by the expert validator can be seen in Table 1.

Table 1. Validity questionnaire grid by media experts

No	Aspect	
	Media Experts	Material Expert
1	Graphics	Appropriateness of content
2	Layout	Suitability of presentation
3	Content	Language suitability
4	Software	

The practicality of the augmented reality-based virtual tour media product was assessed by biology teachers and students after going through a limited trial stage. The practicality indicators can be seen in Table 2.

Table 2. Practicality indicators by teachers

No	Indicators	
	Teachers	Students
1	Ease of use of learning media	Ease of use of learning media
2	Time effectiveness	Time effectiveness
3	Media appeal	Media use
4	Media interpretation	
5	Equivalent	

Qualitative and quantitative data analysis techniques. Interview and observation data were analyzed qualitatively while questionnaire data were analyzed quantitatively. At the validity test stage, the formula used is the Aiken's V (Formula 1). The calculation results are then categorized based on Table 3.

$$V = \frac{\sum s}{n[c-1]} \quad (1)$$

$$s = r - lo$$

Description:
l_o = number of lowest validity assessments
c = number of highest validity assessments
r = number given by an assessor.

Table 3. Aiken's validity assessment categories

No	Aiken's V Scale	Validity
1	V ≤ 0.4	Less
2	0.4 < V ≤ 0.8	Currently
3	0.8 < V	Valid

The results of the practicality test stage can be seen in the practicality questionnaire that has been filled

out previously by students and teachers. While, the Formula 2 was used for assess the product practicality. The results of the practicality assessment and its categories described in Table 4.

$$\%\ Practicality = \frac{Total\ Value}{Maximum\ Value}\ x\ 100\% \quad (2)$$

Table 4. Practicality assessment category

Practicality Level (%)	Categories
81 - 100	Very practical
61 - 80	Practical
41 - 60	Quite practical
0 - 20	Not practical

Results and Discussion

The first step taken is to define the system in general, clarify each user who will use the system, evaluate each hardware and software requirement that will be used, consider the technology or delivery media that will be used in the system to be created. This AR-based virtual tour of the introduction of organelles and the structure of plant and animal cells is an interactive learning media in biology subjects. The purpose of this media is developed as an alternative in understanding and recognizing organelles and the structure of plant and animal cells. This media is built using 3D objects to overcome the limitations of microscopes in the MAN Palopo laboratory. The 3D objects referred to in this study are 3D animal and plant cells. Each 3D visualized on the media will display a description of the name and additional information in the form of the definition and function of each organelle on the 3D object being touched. In accordance with the title of this research, the 3D objects on the media created can also be enlarged so that students can take a virtual tour. In addition, objects can rotate 360 degrees so that students can see the entire 3D structure of animal and plant cells.

Based on the material raised in this study, the target users of AR-based virtual tour media are MAN Palopo class XI students or those of equivalent educational level. Hardware and software requirements are considered in developing AR-based virtual tour media. The devices needed are hardware and software. Hardware such as: *ASUS ROG laptop*, *AMD Ryzen 4000 series 7*, *Nvidia Geforce GTX VGA*, 8 RAM, mouse and keyboard while the software used is: *Unity version 2021*, *Blender 3.5*, *Photoshop* and *Vuforia* account.

This study focuses on creating media that can be operated on students' smartphones offline. However, the development process uses a laptop connected to the internet. Augmented reality (AR) is an innovation based on smartphone technology as a learning medium that aims to improve the quality of learning (Sugiana & Muhtadi, 2019). The way AR works is by displaying visuals that can be seen on devices such as scanners, smartphones, virtual glasses, and webcams. These various special devices will be the output of the AR application visually. The output of AR can be in the form of a 3D model, 2D model, video, image or even animation.

The presence of AR-based virtual tour media can increase students' knowledge by using media that is different from other learning media. In addition, the presence of media is expected to be a good communication bridge between students and teachers in the teaching and learning process so that it is easier for students to understand biology lessons, especially on animal and plant cell organelles. Augmented reality means a media that integrates the real world with the virtual world, meaning that virtual objects are presented in the real world in real time (Billinghurst et al., 2015). Some experts say that marker-based AR is an image recognition technique (Dash et al., 2018). This is because marker-based AR requires an image and a camera to make AR work. If the image is an image located in the database, the AR application will process. Other types of markers that can be recognized can be in the form of cubes or other visual objects. The position and orientation of the marker are one of the determinants of whether AR can be scanned properly in displaying the output of AR that can be seen by its users.

Design Consideration

The design in this study started from creating a 3D object design, marker design, adding audio and user interface design. The metaphor design applied in this study is 3D plant cells and animal cells. Students can choose objects based on the menu they choose and then take a tour of the 3D plant cell and animal cell objects.

The design metaphor is divided into six scenes. The first scene is a display design for the main menu which is the center of the menu for integration into the next menus. This main menu consists of the (1) Play AR menu, (2) close menu, and (3) list menu. The list menu was consists of (1) sound menu, (2) info, and (3) guide. The second scene displays the main menu to access the AR page, while the third scene displays the learning achievement page. The metaphor design for user manual page was lied as

a fourth scene. Moreover, the fifth scene is a metaphor design for the AR page that will display 3D objects when the camera is directed at the previously designed marker. The close sub-scene is the submenu display when clicking the close button. The appearance of each Scene can be seen in Figure 1.

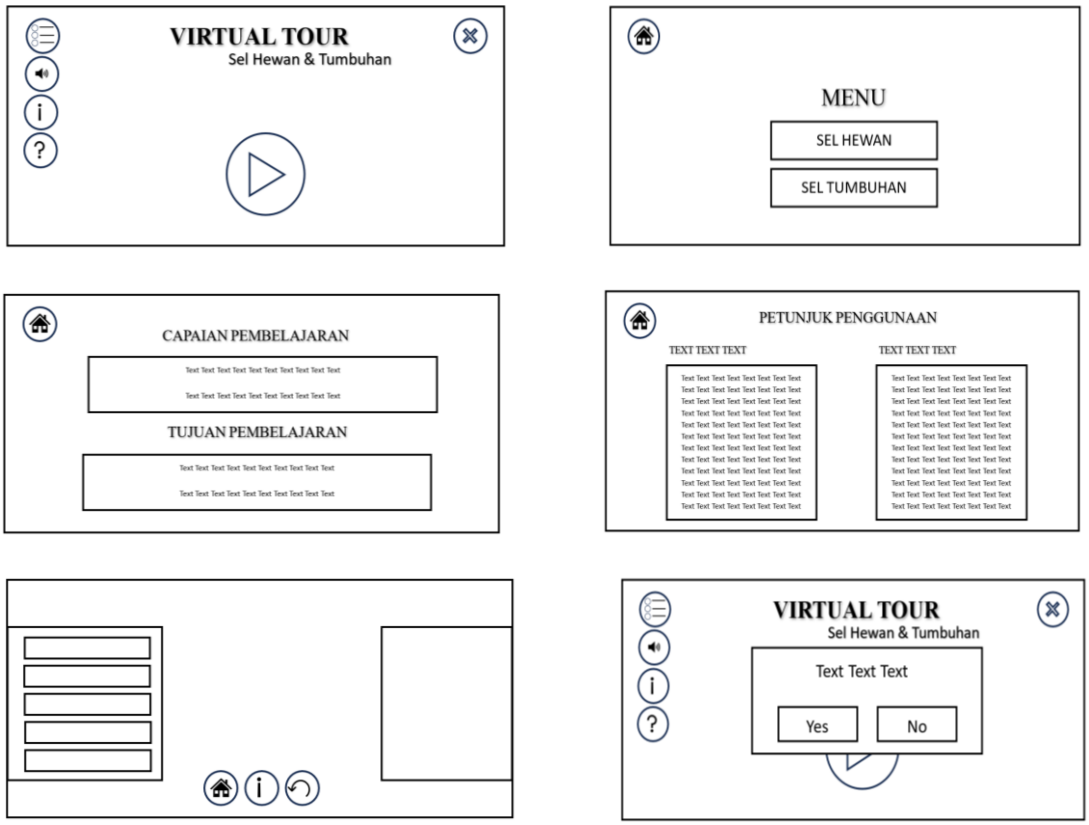

Figure 2. Metaphorical design of each scene

The metaphorical design for markers uses two objects, namely plant cells and animal cells as in Figure 3. Markers are the spearhead of this learning media. When the marker is designed and has a five-star rating, the 3D object will be easier to read (Ahmadi et al., 2017). Meanwhile, there is also a 3D design of the object used as in Figure 4.

Figure 3. Marker

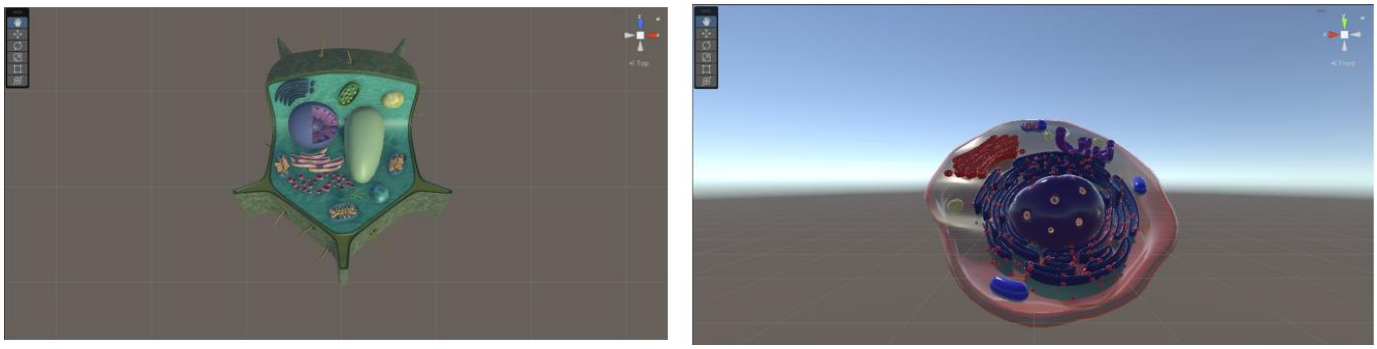

Figure 4. 3D object

Implementation

In the implementation stage, all designs that have been designed in the previous stages are combined in the Unity application. After the AR application has been created, the product prototype is tested to test the level of success of each function in the AR media. The AR-based virtual tour media prototype will be used in beta testing to test the function of each button or menu in the design. The beta testing results show that each button and menu on the media can function properly. After beta testing, the next stage is to test the validity of the media that has been developed which will be tested in terms of material validity and media validity. Figure 4 is a display of the AR-based virtual tour media prototype.

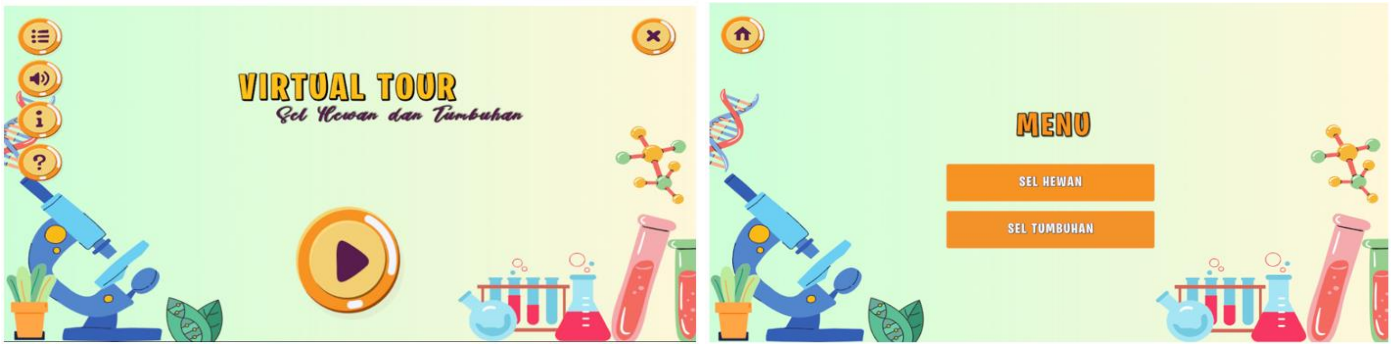

Figure 5. Prototype view

Figure 6. Beta testing results

Beta testing is the first test conducted to determine the level of success of the media developed. In this beta testing, the functions on each media page are tested. Beta testing is carried out in two stages, where the first stage is carried out on the unity application where the virtual tour is developed. The second stage of implementing beta testing is carried out on a smartphone that can be used to run the media.

In the second stage, you must pay attention to the specifications of the device to be used, because when converting an application into an application with an *apk* extension, there are built-in rules that must be considered. Media that has been converted into *apk* can only be run on the Android 8.0 Oreo version with a minimum smartphone RAM of 3GB.

In addition, the AR-based virtual tour media that has been developed can only be implemented on

smartphones that use the Android operating system, apart from that it cannot be run like *IOS* and other operating systems. Figure 6 is beta testing on an Android smartphone by paying attention to the previously determined specifications, each feature functions properly, the markers that appear are also in accordance with their descriptions. The results of the learning media validity test carried out by two experts in their respective fields, namely media experts and material experts. The developed results of media validity test described in Table 5.

Table 5. Validity test results

Validator	Percentage (%)	Category
Media expert	94.56	Valid
Material expert	97.75	Valid
Average	96.16	Valid

In general media that has been declared valid by both experts. Validity of AR-based virtual tour media conducted by two experts, namely media experts and material experts. The validity of the material expert after seeing the contents of the media material, there are several additional materials that are considered necessary to be included. The first is the title of the media, the initial title is "*Virtual tour of Animal and Plant Cells*" changed to "*Virtual tour of Animal and Plant Cell Structure and Organelles*". The title change can be seen in Figure 1. On the Menu page, it can be seen in Figure 5, it must also be changed, which was previously a button with the description "*Animal Cells*" and "*Plant Cells*" changed to "*Animal Cell Organelles*" and "*Plant Cell Organelles*". In addition to changing the title, other input is to remove some information that does not match the function of the mitochondrial organelle, such as removing sentences that contain the meaning mitochondria do not contain nerve cells and muscle cells. In the peroxisome organelle, the explanation of plant cells was also removed. Furthermore, the material expert gave suggestions to add information about the function of vacuoles, the function of chloroplasts and the function of centrioles. After making revisions, it was tested again for the pages that had been added. The results of the trial can run according to the button commands. Like the home button can function to return to the main menu page. The validation results show that this media has accurate content, is in accordance with the curriculum, and is technical and can be operated well by students. Cell organelle models displayed in 3D and interactive form provide a more real and immersive visual experience compared to conventional learning media.

Virtual tour is a technology that makes its users feel like they are in a place, either not real but as if real, which allows users to significantly increase their ability to see, capture and analyze virtual data (Husna et al., 2021). One of the virtual tours is used to provide the experience of 'having been' in a place just by looking at the monitor screen. The presentation of virtual tours can be done by utilizing images or videos, in addition to using three-dimensional models (Wulur et al., 2015). Students who are involved in utilizing virtual tours show more active involvement in learning activities (Allcoat & von Mühlenen, 2018).

Evaluation

The evaluation process uses a practicality test to measure the ease, effectiveness of time used and the usefulness of the media. AR-based virtual tour media that was developed after being declared valid by experts and experts in their fields, the next step is a limited trial or practicality test carried out by research subjects in class. The student practicality test scores can be seen in Table 6.

Table 6. Student response results

No	Aspect	Percentage (%)	Category
1	Ease of use of learning media	88.67	Very practical
2	Time effectiveness	86.83	Very practical
3	Media use	88	Very practical
	average	87.83	Very practical

The purpose of the practicality test on students is to see how easy it is for students to use the media, the effectiveness of time and convenience. Based on the contents of the questionnaire that has been distributed to students, it was concluded that AR-based virtual tour media is very practical. This is because the media can be taken anywhere without an internet connection and is not limited by time. The markers are also easy to find in the media that has been uploaded to Google Drive. The 3D objects embedded in the media feel very real, so that students seem to be touching the cell organelles. The basic function that is the object of the research is a virtual tour, where students can enlarge 3D so that the cell organelles look bigger and clearer. Students can also find out the shape and position of the cell organelles that they want to know the information about. In addition to the function of enlarging, students can also rotate 3D objects so that students can see the entire organelles of animal and plant cells.

According to students who have conducted limited tests or practicality tests, they said that their tendency

to use smartphones in their daily lives makes it easier for students to access and is very helpful in understanding the materials in the media. In addition, the 3D objects displayed also make students more curious about the functions of organelles contained in the media (Yazici & Sözbilir, 2024). In general, it is very practical, which means that learning media is easy for students to use because it is more flexible. In addition to testing students' practicality, teachers also conducted trials on the AR-based virtual tour media that was developed, which can be seen in Table 7.

Table 7. Teacher response results

No	Aspects	Percentage (%)	Category
1	Ease of use of learning media	98	Very practical
2	Time effectiveness	85	Very practical
3	Media appeal	95	Very practical
4	Media interpretation	98	Very practical
5	Equivalent	98	Very practical
	Average	95	Very practical

Practicality tests were also conducted on biology teachers who taught in the class, from the results of the practicality test it was stated that AR-based virtual tour media was very practical, in line with what his students said, because it can be accessed anytime and anywhere. Not limited by time, only limited by smartphone power. The materials presented are also easy for students to understand because the 3D models displayed are very interesting and have been taught. Students who have learned to use virtual tours show a positive attitude towards their learning environment (Markowitz et al., 2018), increase interest in learning and minimize learning difficulties (Wibowo et al., 2020). Augmented reality-based virtual tour learning media is one alternative interactive media that can be used by teachers in the classroom to support the achievement of learning objectives, especially in the introduction to cell organelles material.

Conclusion

Virtual tour media for augmented reality-based cell organelle introduction material has been tested for validity by two media experts and material experts. The validation results of both showed valid results, meaning that the media is suitable for use as a learning medium to support the quality of learning in the classroom. Virtual tour media is easy to use by teachers and students based on practicality tests. The presence of virtual tour media based on augmented reality in cell introduction material is in accordance with the needs of students. Its presence is able to facilitate students in recognizing each microscopic cell organelle so that it looks real. Students learn to use smartphones as if they are able to surround each organelle in the cell so that meaningful learning is created. Hopefully in the future there will be more varied virtual tour media in biology subjects. It is because there are many materials that require visualization so that it is hoped that students will find it easier to learn biology subjects. The use of AR-based virtual tours in learning allows students to learn independently (self-paced) outside the classroom and can increase the learning experience to be more interactive and interesting for students. Further research could develop the AR-based Virtual Tour to cover other biological topics besides cells such as viruses and human organ systems.

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Author Contributions

A. S. Laswi: methodology, analysis; **A. S. Laswi** and **B. Bungawati:** writing original draft preparation, and **A. S. Laswi** and **B. Bungawati:** review and editing.

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