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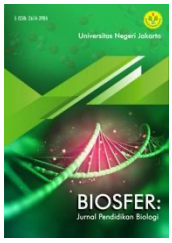

AR-Senses: Development of an effective biology learning media for human sensory systems

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ABSTRACT

Biology is a scientific field those studies living things with a very broad subject matter, one of which is the coordination system material that discusses the human sensory system. Effective and efficient Biology learning process requires the latest digital technology-based learning media such as Augmented Reality. The objectives of this study are 1) to develop Augmented Reality-based AR-Senses application for human sensory system material, 2) to test the feasibility of AR-Senses application as a learning media, 3) to know the response of teachers and students to AR-Senses application. AR-Senses is developed into a biology learning application that can be run on Android smartphones with the main feature of Augmented Reality and supported by animated video features, short material, and practice quizzes. This research uses the Research and Development (R&D) method with development stages according to the ADDIE model. Data collection used a feasibility validation questionnaire and a response questionnaire to the AR-Senses application. The data analyzed were the results of the feasibility assessment of the AR-Senses application from media experts, material experts, and linguists, as well as the results of responses from Biology teachers and students. The results showed that the AR-Senses application received a media feasibility score of 82%, material feasibility of 82%, language feasibility of 85%, and with an average score of Biology teacher and student trial results of 84.5%, so overall the AR-Senses application received a very feasible category as a learning medium.

INTRODUCTION

The linkages in the world of science comprehensively characterize the progress of the 21st century, where the synergy of knowledge across scientific fields accelerates the development of education (Gürültü et al., 2019; Sudarisman, 2015; Sunarno et al., 2023). An educator is required to be professional and adaptive to the development of the times, so in order to advance education, teachers must prepare learning media that adapt to the characteristics of students along with the development of technology, because students usually tend to follow the progress of technology that is developing (Abrianto et al., 2024; Hamdjah et al., 2024; Muliana, 2024).

Biology is a field of science that studies life and has a very broad scope of subjects (Köse, 2024; Reece et al., 2014). Biology also includes systems that exist in living things, one of which is the human sensory system. The human sensory system discusses the structure and function of the sensory organs, the mechanisms of the sensory system, and disorders or diseases that occur in the human sensory system (Refirman et al., 2016; Reiss & Tunnicliffe, 2001). Biology learning requires learning media that can interpret Biology materials and is easy to use for teachers and students (Festiyed et al., 2019; Nugraha, 2018; Rustaman et al., 2005).

The problem that is often seen in students today is the lack of motivation to learn, which is caused by learning media that is not interesting enough and does not follow technological developments, even though the characteristics of students in general always follow and like the technology that is currently developing (Festiyed et al., 2019; Kumalasari et al., 2024; Kwon & Silva, 2019; Nursakinah et al., 2023). The statement is in accordance with the results of the needs analysis that has been conducted on 47 students in four high schools in Jakarta, as well as on nine Biology teachers in six high schools in Jakarta. The needs analysis was conducted as an initial step to determine the need for media development and adjustment of the material to be achieved.

The results of the analysis of student needs show that the learning media often used in schools is still not very interesting, in addition, students currently prefer learning applications with additional interactive 3D image features (Festiyed et al., 2019; Nursakinah et al., 2023). The results of the needs analysis of high school Biology teachers also show that in delivering human sensory system material, learning media such as applications that are easy to use and have interesting learning features are needed, because learning media in schools require the development of media that is more supportive for delivering material concepts. Based on these problems, it is very important for an educator to prepare a learning strategy that can solve various problems in learning (Ristanto et al., 2017). The right solution to overcome this problem is one of them by implementing learning media that is appropriate to the needs and characteristics of students (Nugraha, 2018; Nurseto, 2012; Sadiman et al., 2014).

Learning media is anything that can be used to convey messages in the form of learning materials by the sender (educator) to the recipient (student) so that it can stimulate the thoughts, feelings, attention, and interests and attention of students so that the learning process occurs (Isfaeni et al., 2018; Muliana, 2024; Sadiman et al., 2014). The material can be accepted by students if an educator can use learning media that can stimulate students to learn (Reiser & Gagné, 1982). Learning media is a small part of learning technology that needs to be created, designed, and developed, and managed (evaluated) with the aim of achieving effectiveness and efficiency in the learning process (Arsyad, 2017; Nurseto, 2012; Wati, 2016).

The digital revolution and technological disruption in the industrial era 4.0 are marked by the development of new technologies, which have given rise to many innovations that can be managed as opportunities to advance education (Ghufron, 2018). Augmented Reality technology is a digital media technology that is currently being developed. This technology provides one of the interesting features that displays interactive 3D graphics (Arifiani et al., 2013). Augmented Reality has many benefits and advantages for scientists (Pierdicca et al., 2015). Augmented Reality has also been used in the medical field (Wardhono et al., 2015). business activities (Rifa'i et al., 2014) and tourism (Tahyudin et al., 2015), and has also been widely developed as a learning medium (Mantasia & Jaya, 2016; Rini et al., 2022). The advantages of Augmented Reality, which provides 3D and interactive features, are very interesting to be developed into a superior feature for Biology learning applications, especially in the material on the human sensory system, because this material contains objects of sensory organs that will be easier to understand if visualized into three-dimensional objects (Annisa & Subiantoro, 2023). Support for video mechanism features in learning media also allows students to better understand concepts (Rusdi et al., 2018).

This research aims to develop an Augmented Reality-based application as a Biology learning medium on the human sensory system material. This media is designed into an AR-Senses application developed on an Android smartphone, this application is supported by the Augmented Reality feature and also has other features such as material menus and quizzes, plus animated videos of the human sensory system mechanism which are expected to be a learning medium that makes it easier for teachers to deliver material and makes it easier for students to learn the human sensory system. The results of the media from this development are expected to be used as research material in the implementation of learning, especially Biology subjects, so that the AR-Senses application can be useful and widely implemented.

METHODS

Research Design

This research uses the research and development method or R&D (research and development). In the field of education, R&D research is used as a process of developing learning media which is carried out through a series of research with various methods in a cycle that goes through various stages (Ali & Asrori, 2014). The ADDIE model is designed in a programmed manner with a systematic sequence of activities in an effort to solve learning problems related to learning media that are appropriate to the needs and characteristics of students (Tegeh & Kirna, 2013).

The development steps taken are based on the ADDIE development model.The ADDIE development model consists of five stages as the name suggests, namely (1) analysis, (2) design, (3) development, (4) implementation, (5) evaluation (Branch, 2009; Tsai & Chou, 2023).

Figure 1. ADDIE model framework

1) Analyze

The analysis stage is the initial stage which aims to find out problems in Biology learning (Ristanto et al., 2020), especially regarding the use of learning media in schools for human sensory system material which is considered difficult by some students (Evriyani et al., 2018). The activities carried out at this stage are compiling teacher and student needs analysis instruments to be distributed to schools (Tegeh & Kirna, 2013). The teacher needs analysis instrument was distributed to six high schools in Jakarta, and for the student needs analysis it was distributed to four high schools in Jakarta. The data obtained was then analyzed and used as a reference in developing learning media that are in accordance with the needs of teachers and students.

2) Design

Design is the stage where development planning is carried out after obtaining data from the results of the needs analysis.Good design planning will help developers to save development time and costs (Tegeh et al., 2014). At this stage, it consists of media layout design activities, content adjustments, application feature design, trial strategy design, and research instrument design. Next, a storyboard and product prototype are created to describe the AR-Senses application design that will be developed (Ristanto et al., 2018).

3) Development

Development is the stage in which the application is created *AR-Senses,* which will then be validated. Validation is an assessment of the product developed to determine the feasibility and quality of AR-Senses learning media. The assessment criteria for validation are in terms of media, materials, and language, each of which is validated by two experts in their fields, namely lecturers or teaching staff

who have completed at least a master's degree in education or biology and have experience conducting research on learning media. After this learning media is declared valid, a product trial will be conducted on Biology teachers and small group students.

In the development of Augmented Reality media, there are four components required, namely hardware, software, scanner (scanning tool), and marker as a marker (Annisa & Subiantoro, 2023; Arifitama, 2017). Some software that can be used to create Augmented Reality applications include Unity-3D, Vuforia and Blender as programs to create three-dimensional models, and Photoshop or CorelDraw as programs to create two-dimensional models.

4) Implementation

At this implementation stage, the AR-Senses application product was tested in large groups, which was carried out on 90 students in class XI majoring in mathematics and natural sciences (MIPA) from three classes in a high school. This activity is carried out by implementing learning using the AR-Senses application, then distributing the analysis of student responses to the use of learning media with the AR-Senses application.

5) Evaluation

Summative evaluation is the final stage which aims to improve the AR-Senses application product based on the results of media response analysis (Sahertian & Muladi, 2013). After the improvements were made, the AR-Senses application product was Feasible of being a learning medium and ready to be used in Biology learning of human sensory system material.

Population and Samples

Media implementation was carried out in four classes of XI MIPA SMA with a population of 144 students, but the sample determined was 90 students from 3 classes for implementation through a learning process using the AR-Senses application. Sample selection used purposive sampling, namely based on the availability of communication tools (Android smartphones) in each class and the condition of students who had never studied human sensory system material (Sugiyono, 2015).

Instrument

The research instruments used in the development of AR-Senses learning media include student needs analysis instruments, teacher needs analysis instruments, material feasibility test instruments, media feasibility test instruments, language feasibility test instruments, teacher trial instruments, student trial instruments, and response analysis instruments for the results of using AR-Senses learning media.

Table 1.
Data Collection Techniques and Instruments

Stage	Technique	Instrument	Target
Analysis (McKillip, 1987)	Needs analysis	Questionnaire	Students and teachers
Development (Muhsan, 2022; BSNP, 2014)	Material feasibility test	Questionnaire	Two experts each
	Media suitability test	Questionnaire	
	Language adequacy test	Questionnaire	
	Small group trials	Questionnaire	Teachers and Students
Implementation (Iba & Wardhana, 2024; BSNP, 2014)	Large group response analysis	Questionnaire	Learners

Procedure

The AR-Senses application was developed using the ADDIE model with the stages (1) analysis, (2) design, (3) development, (4) implementation, (5) evaluation (Branch, 2009; Tegeh & Kirna, 2013). The application feasibility validation process is carried out by media experts, material experts, and language experts. Then, a trial process is carried out on Biology teachers, small group trials, and large group trials to obtain the results of the response to the use of the AR-Senses application. The brief development stage procedure can be seen in the following table:

Table 2.
Research procedure flow

ADDIE Stages	Procedures performed
Analyze	1) Student needs analysis 2) Learner analysis 3) Material analysis of the human sensory system
Design	1) Application storyboard design 2) Create research instruments
Development	1) Development of the AR-Senses application 2) Validation of feasibility by media, material and language experts 3) Test the application on teachers and small groups of students
Implementation	Test the application on large groups of students
Evaluation	Improvements of the AR-Senses application

Data Analysis Techniques

The results of validation and testing of AR-Senses learning media by experts will produce data that will then be analyzed. The analysis technique used is a quantitative data analysis technique. The percentage of data obtained is converted based on a scale assessment of 1-5, namely with a score of 1 indicating the criteria "very poor", a score of 2 indicating "poor", a score of 3 indicating "sufficient", a score of 4 indicating "good", and a score of 5 indicating "very good".

The AR-Senses application eligibility quality score is obtained based on the following formula:

$$Score = \frac{value\ obtained}{maximum\ value} \times 100\%$$

Once the percentage value is obtained, the feasibility of the AR-Senses application can be determined based on the interpretation of the feasibility test scores from BSNP (2014). The presentation results in a range of 81%-100% interpreted as "very feasible", a range of 61%-80% is "feasible", a range of 41%-60% is "quite feasible", a range of 21%-40% is "not feasible", and a range of 0%-20% is interpreted as "very not feasible".

RESULTS AND DISCUSSION

Design Plan

The design process produces a picture of the media content in the form of a storyboard, which is used as a reference at the development stage (Nurseto, 2012; Tegeh et al., 2014). The creation of this storyboard is made according to the content of the material on the learning device and visualized in a storyboard design in a directed and systematic manner according to the researcher's idea, then depicted into a design similar to the expected final appearance. At this stage, the iconic AR-Senses application logo design was also created and illustrates the philosophy of learning the human sensory system. The following is a logo and storyboard design made using CorelDRAW X7 and Photoshop CC.

This application has the logo AR-5enses (image a) which is a combination of the word "AR" which means Augmented Reality, then the word "5enses" from the English word "Senses" which means Indra. In the word 5enses, the number 5 is used in the first letter to replace the letter S which means that the human sense organs consist of 5 organs. There are 5 icons of human sense organs above the letters enses meaning eye-nose-skin-ear and -sense of taste (tongue). The appearance of a logo like this can illustrate that this application is a learning media for the human sense system based on Augmented Reality. In the layout display (image b) and menu display (image c).

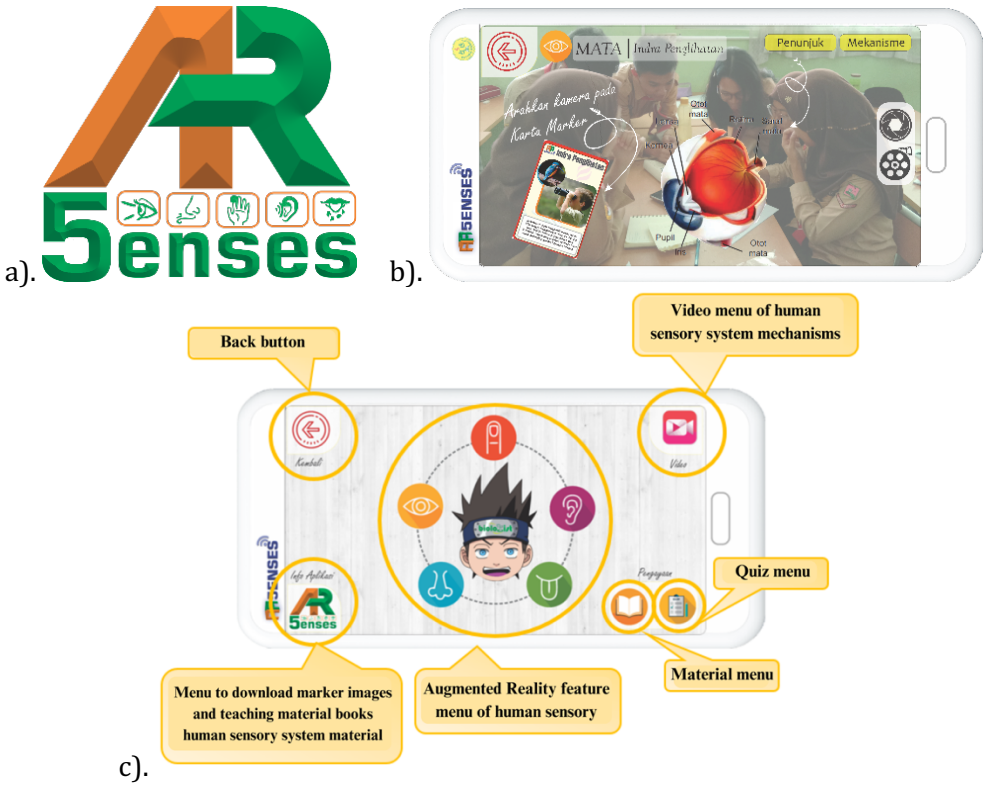

Figure 2. Storyboard design draft. a. AR-Senses logo, b. Augmented Reality Feature, c. AR-Senses menu display

Application Development

Media development is designed carefully to produce the final product in the form of an AR-Senses application and also a marker that is made into an AR-Senses E-Book. The software used to create 2D image designs is CorelDRAW X7 and Photoshop CC, while to create 3D images using Unity-3D software. 2D design is used to create a layout display in the application and also to create other 2D image objects such as marker objects. While 3D design is used for Augmented Reality objects, namely images of 5 human sensory organs. After the 2D marker image and 3D sensory object have been created, the next step is to configure the object using the Vuforia SDK software to become an Augmented Reality object (Pamoedji et al., 2017).

Augmented Reality is the main feature in the AR-Senses application that can display human sensory organ image objects in 3D and interactively, but this application also adds animated video features for the mechanism of the sensory system, sensory system materials, and quizzes for practice. These features are made according to the results of the needs analysis and design design to become an effective and interesting learning media (Evriyani et al., 2018; M. Rusdi, 2018).

The final stage of application development is to change the application format so that it can be displayed on an Android smartphone, the device specifications to be able to run AR-Senses are a minimum Quadcore processor with a minimum version of Android 4.3.1, a minimum of 2 GB RAM, and a minimum of 4 MP camera. Here are some images of the results of the AR-Senses application development in Figure 3.

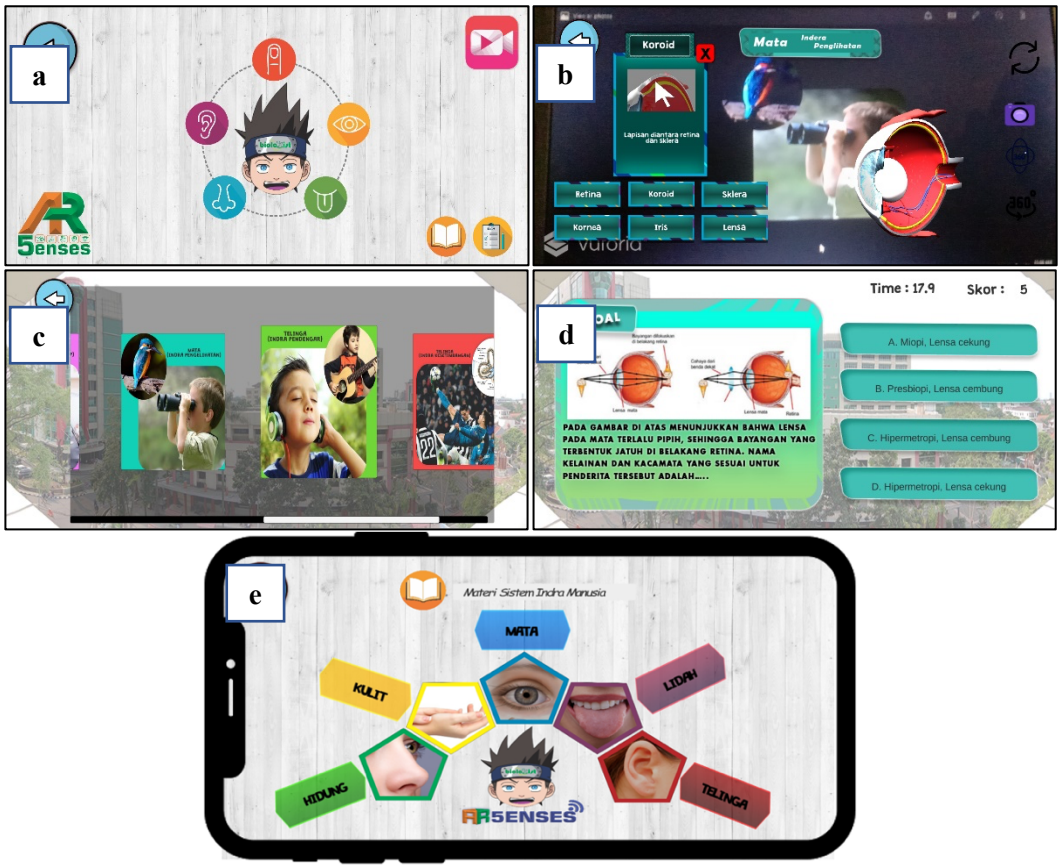

Figure 3. AR-Senses Development Results Display. a. Main menu, b. Augmented Reality feature of the eye organ, c. Video menu of the mechanism of the sensory system, d. Practice quiz feature, e. Menu of selected features of the human sensory system material.

Application Feasibility Test

The feasibility test or validation is carried out to test the level of feasibility of the application, to test this feasibility, an assessment of the application's feasibility test instrument is carried out in terms of media, materials, and language by expert validation, then a trial is carried out on Biology teachers and a trial on small group students.

1) Media Expert Validation Test

The feasibility test of the application in terms of media was carried out by assessing an instrument consisting of 15 questions, making instrument questions based on the scope of aspects and several indicators. Based on the results of the media feasibility test, the AR-Senses application received the category "Very Feasible", with an average value of 82%. The following are the results of the media feasibility test that have been tested by two expert validators.

Table 3.
Media Feasibility Test Results by Expert Validators

No	Aspect	Assessment Indicators	Average	Criteria
1	Presentation of features in the application	General overview	75%	Feasible
		Completeness of AR-Senses application features	80%	Feasible
		The appeal of interactivity	85%	Very Feasible
2	Application eligibility	General description	83%	Very Feasible
		Augmented Reality feature quality	85%	Very Feasible
		Average overall rating	82%	Very Feasible

2) Material Expert Validation Test

The content of the material displayed in the application is in the form of the main Augmented Reality feature that displays sensory objects in 3D, a literacy material menu, a video of the mechanism of the sensory system, and quiz content. The content containing the material is assessed with a material feasibility test by a material expert validator. The material feasibility test instrument consists of 20 questions covering two aspects and seven assessment indicators. Based on the results of the material feasibility test, this application received the category "Very Feasible" with an average score of 82%. The following is a table of the results of the material feasibility test that has been tested by two expert validators.

Table 4.
Material Feasibility Test Results by Expert Validator

Aspect	Assessment Indicators	Average	Criteria
The suitability of AR-Senses application content as a learning medium	Suitability of product content with curriculum	76%	Feasible
	Accuracy of substance with learning media	80%	Feasible
	Legibility	80%	Feasible
Presentation of material related features	General description	85%	Very Feasible
	Effectiveness of material presentation	90%	Very Feasible
	Attraction and motivation	83%	Very Feasible
	Suitability to targets (students)	80%	Feasible
Average overall rating		82%	Very Feasible

3) Language Expert Validation Test

The language feasibility test was conducted to assess the suitability of the language contained in the literacy material content; the assessment used a language validation instrument consisting of 10 questions based on six assessment indicators in the instrument grid. Based on the results of the language assessment by expert validators, the AR-Senses application received the category "Very Feasible", namely with a total average score of 85%. The following is a table of the results of the language feasibility test by expert validators.

Table 5.
Language Eligibility Test Results by Expert Validators

No	Assessment Indicators	Average	Criteria
1	Suitability to the level of student development	85%	Very Feasible
2	Writing system	90%	Very Feasible
3	Legibility	75%	Feasible
4	Clarity of sentences	90%	Very Feasible
5	Use of terms and symbols	90%	Very Feasible
6	Giving motivation	80%	Feasible
	Average overall rating	85%	Very Feasible

Based on the results of the application feasibility test in terms of media, material, and language by expert validators, the overall average results were obtained, which can be seen in Figure 4.

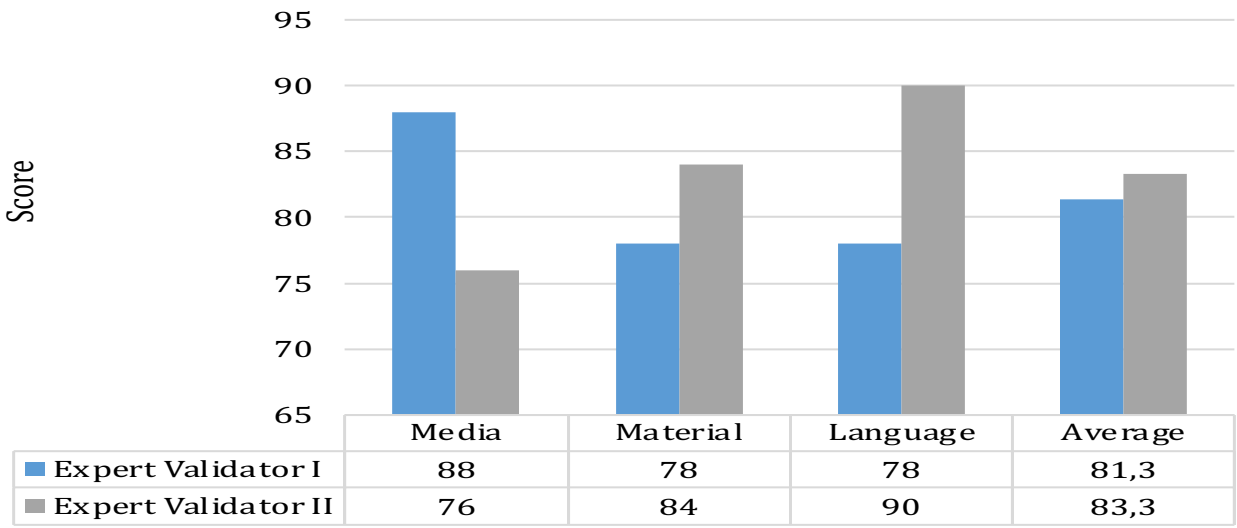

Figure 4. Graph of AR-Senses Application Feasibility Test Results by Expert Validator

Based on the graph above, the average score by expert validator I for testing media, materials, and language got a score of 81.3%, while the results by expert validator II got an average score of 83.3%. So the interpretation of the feasibility of the AR-Senses application from the expert validator shows that the application is "Very Feasible" for use. However, the results of this test need to be tested further on Biology teachers and small groups, so that they can be developed to be better. The following are details of the results from each expert in the application feasibility test.

4) Trial by Biology Teacher

Testing the AR-Senses application after the validation test is feasible, then the application trial is carried out on Biology teachers. This test uses an instrument containing 20 questions referring to three aspects and several indicators. The test results obtained an average score of 81% with the category "Very Eligible" (Table 6).

Table 6.
Biology Teacher Trial Results

No	Aspect	Assessment Indicators	Average	Category
1	Contents	Suitability of application content with curriculum	93%	Very Feasible
		Media accuracy with the development of science and technology	80%	Feasible
		Conceptual suitability	80%	Feasible
		Accuracy of quizzes and practice questions with material concepts	80%	Feasible
2	Appearance	Compatibility of AR, video and image features	80%	Feasible
		Compliance of graphic display and menu features	80%	Feasible
		Ease of use	80%	Feasible
		Impressions on usage	80%	Feasible
3	Benefit	Providing motivation in learning	80%	Feasible
		Encouraging students to think critically	80%	Feasible
		Average overall rating	81%	Very Feasible

5) Trial by small group students

The AR-Senses application trial was also tested on a small group using a media trial instrument by students consisting of 10 questions according to the assessment indicators. The small group test was conducted by 15 high school students. The results showed that AR-Senses was "Very Eligible" with a total score of 87.7% (Table 9).

Table 7.
Small Group Trial Results

No	Aspect	Assessment Indicators	Average	Category
1	Contents	Features make it easier to master concepts	89%	Very Feasible
		Conformity of content to material concept	91%	Very Feasible
		Completeness of application features	85%	Very Feasible
2	Appearance	Layout fit, and AR images	81%	Very Feasible
		Image and Video Quality	88%	Very Feasible
		Ease of use and responsiveness	88%	Very Feasible
		Easy and attractive menu display	95%	Very Feasible
		View quiz features and materials	91%	Very Feasible
3	Benefit	Increase motivation in learning	83%	Very Feasible
		Helping students master concepts	87%	Very Feasible
Average overall rating			88%	Very Feasible

6) Implementation by Large Group Students

The media implementation was carried out in four grade XI MIPA SMA through the human sensory system learning process. A total of 144 student populations in four classes were used as many as 90 students from 3 classes as samples to be implemented through the learning process using the AR-Senses application. After the learning process, a questionnaire was given to analyze the response to the use of AR-Senses media to students. The questionnaire is an assessment instrument containing 10 questions that refer to several aspects and indicators. The results obtained from the media implementation process show that the AR-Senses application is "Very Eligible" to be used as a learning medium, namely with an average total score of 86% (Table 10).

Table 8.
AR-Senses Application Implementation Results

Aspect	Average	Category
Contents	87%	Very Feasible
Appearance	85%	Very Feasible
Benefit	84%	Very Feasible
Average overall rating	85%	Very Feasible

Results and Summative Evaluation

The final stage of research design from media development is to conduct a summative evaluation, which is the media refinement stage that refers to the overall results of validation, testing, and implementation. The following is a graph of the overall AR-Senses application assessment results which can be seen in Figure 5.

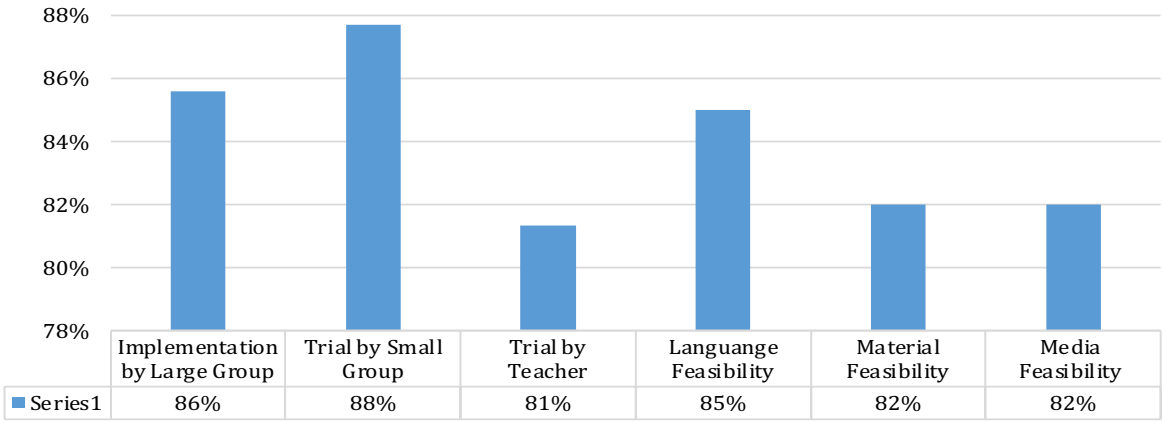

Figure 5. AR-Senses Overall Assessment Results Graph.

Based on the results of the feasibility test, the results of the media trial, and the results of the response at the implementation stage, input and suggestions were obtained regarding the product as material for improvement, so that the media developed would be of higher quality (Ristanto et al., 2020; Sahertian & Muladi, 2013). Some of the input and suggestions from expert validators are to improve the layout display section and quiz questions, as well as adding some information about the application. The average overall assessment result of the AR-Senses application got an average score of 84% with the category "Very Eligible" and received good comments from most students, so the final improvement was only by re-checking the appearance and features of the AR-Senses application, as well as increasing the responsibility process for media improvement.

The AR-Senses application that has been developed as a Biology learning media for the human sensory system material certainly has weaknesses and strengths. Based on a series of feasibility tests and trials conducted, the weakness of the AR-Senses application is that the file size is relatively large for mobile phones with low memory specifications, and this application has not been developed for the iPhone, making it possible for some students to have difficulty installing the AR-Senses application. However, the AR-Senses application has many advantages as a Biology learning medium, including AR-Senses has the main feature of Augmented Reality which is the latest technology for displaying objects in 3D and interactively and has its own interesting value for students, in addition the AR-Senses application is also supported by other features such as video mechanisms, short materials, and quizzes that encourage students to master the concept of the human sensory system.

The AR-Senses application with Augmented Reality features that can be run on Android is a learning medium that is favored by students. Android applications provide convenience and can improve learning activities, because they can be used anytime and anywhere. This shows that AR-Senses is an interesting, interactive, and effective application as a learning medium in improving teaching and learning activities. (Mustaqim & Kurniawan, 2017; Nurhasanah et al., 2019; Suryanda et al., 2018). The AR-Senses application that has been developed will then be uploaded to Playstore and Appstore, with the hope of becoming a biology learning media that can help high school students understand the material on the human sensory system more easily.

CONCLUSION

The AR-Senses application that has been developed into a learning media through a research and development process received an average score from the results of the feasibility test by expert validators of 82.3%, a trial by Biology teachers of 81%, a trial by small group students of 88%, and the results of the implementation response of large groups of 86%, so this application received an assessment with a very feasible category to be used as a support for Biology learning on the material of the human sensory system.

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REFERENCES

Abrianto, A., Amaefuna, I., & Onyemowo, A. (2024). Biology Learning Innovation Using Booklet Media. *Journal of Academic Biology and Biology Education*, *1*, 75–81. https://doi.org/10.37251/jouabe.v1i2.1158

Ali, M., & Asrori, M. (2014). *Metodologi dan Aplikasi Riset Pendidikan* (Suryani, Ed.; 1st ed.). Bumi Aksara.

Annisa, D. N., & Subiantoro, A. W. (2023). Developing a mobile augmented reality for facilitating socio-scientific issue-based biology learning. *Biosfer*, *16*(1), 66–81. https://doi.org/10.21009/biosferjpb.29429

Arifiani, S., Kuswardayan, I., & Sunaryono, D. (2013). Pembuatan Game " Ant Smasher " Berbasis Augmented Reality dengan Mengimplementasikan Tombol Virtual. *Jurnal Teknik Pomits*, *2*(1), 2–4. http://digilib.its.ac.id/public/ITS-paper-32816-5109100114-Paper.pdf

Arifitama, B. (2017). *Panduan Mudah Membuat Augmented Reality* (Seno, Ed.; 1st ed.). Andi Offset.

Arsyad, A. (2017). *Media Pembelajaran* (A. Rahman, Ed.; Revisi). PT Raja Grafindo Persada.

Badan Standar Nasional Pendidikan. 2014. Instrumen Penilaian Buku Teks Pelajaran Tahun 2014. http://bsnp-indonesia.org/2014/05/28/instrumen-penilaian-buku-tekspelajaran-tahun-2014/

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach* (1st ed.). Springer US. https://doi.org/10.1007/978-0-387-09506-6

Evriyani, D., Rusdi, R., & Indraswary, A. (2018). Pengembangan Komik Berbasis Peta Konsep sebagai Media Pembelajaran pada Materi Sistem Saraf di SMA. *Biosfer: Jurnal Pendidikan Biologi*, *9*(2), 14–22. https://doi.org/10.21009/biosferjpb.9-2.3

Festiyed, Djamas, D., & Ramli, R. (2019). Learning model based on discovery learning equipped with interactive multimedia teaching materials assisted by games to improve critical thinking skills of high school students. *Journal of Physics: Conference Series*, *1185*(1), 12054. https://doi.org/10.1088/1742-6596/1185/1/012054

Ghufron, M. A. (2018). Revolusi industri 4.0: Tantangan, Peluang dan Solusi bagi Dunia Pendidikan. *Seminar Nasional Dan Diskusi Panel Multidisiplin Hasil Penelitian Dan Pengabdian Kepada Masyarakat*, 332–337. http://www.proceeding.unindra.ac.id/index.php/dispanas2018/article/viewFile/73/45

Gürültü, E., Aslan, M., & Alci, B. (2019). Ortaöğretim öğretmenlerinin 21. yüzyıl becerileri kullanım yeterlikleri- Competence for 21th century skills use of secondary school teachers. *Eğitim Fakültesi Dergisi*, *34*. https://doi.org/10.16986/HUJE.2019051590

Hamdjah, A., Alimin, A., & Sudding, S. (2024). The Effect of Interactive e-Module Learning Media Based on the Canva Application on the Discovery Learning Model on the Motivation and Learning Outcomes of Class XI MIPA Students of SMAN 7 Bulukumba (Study on Basic Material of Acid-Base Solutions). *ChemEdu*, *5*, 43. https://doi.org/10.35580/chemedu.v5i3.49754

Iba, Zainuddin., Wardhana, A. (2024). Operasionalisasi Variabel, Skala Pengukuran & Instrumen Penelitian Kuantitatif. Purbalingga: CV. Eureka Media Aksara

Isfaeni, H., Corebima, A. D., Suwono, H., & Rohman, F. (2018). The effectiveness of the printed books as a learning material in a one-day the molecular biology course. Biosfer: Jurnal Pendidikan Biologi, 11(2), 108–113. https://doi.org/10.21009/biosferjpb.v11n2.108-113

Köse, E. (2024). Biology Teacher Candidates Drawings about Circulatory System. *Science Insights Education Frontiers*, *23*, 3779–3797. https://doi.org/10.15354/sief.24.or621

Kumalasari, A. P., Harlita, & Rinanto, Y. (2024). Development of circulatory system mobile learning (CSML) for grade XI students. *Biosfer*, *17*(2), 590–601. https://doi.org/10.21009/biosferjpb.41502

Kwon, H. R., & Silva, E. A. (2019). Mapping the Landscape of Behavioral Theories: Systematic Literature Review. *Journal of Planning Literature*, *35*(2), 161–179. https://doi.org/10.1177/0885412219881135

Mantasia, & Jaya, H. (2016). Pengembangan Teknologi Augmented Reality Sebagai Penguatan dan Penunjang Metode Pembelajaran di SMK untuk Implementasi Kurikulum 2013. *Jurnal Pendidikan*

Vokasi, *6*(3). https://journal.uny.ac.id/index.php/jpv/article/view/10522/8701
McKillip, J. (1987). Need analysis. SAGE Publications, Inc., https://doi.org/10.4135/9781412985260
Muhsan, R., Hanim, N., Zuraidah. (2022). Analisis Kelayakan Media Pembelajaran Interaktif Prezi Berbasis Metode Problem Solving pada Materi Perubahan Lingkungan. Prosiding Seminar Nasional Biotik. 10 (1), 52-59. http://dx.doi.org/10.22373/pbio.v10i2.14246.g7186
Muliana, G. (2024). Literature Review: Innovations in Biology Learning Media. *EduLine Journal of Education and Learning Innovation*, *4*(4), 477–484. https://doi.org/10.35877/454RI.eduline2842
Mustaqim, I., & Kurniawan, N. (2017). Pengembangan Media Pembelajaran Berbasis Augmented Reality. *Jurnal Edukasi Elektro*, *1*, 36–48. http://journal.uny.ac.id/index.php/jee/
Nugraha, I. (2018). The use of drawing as an alternative assessment tool in biology teaching. *Journal of Physics: Conference Series*, *1013*(1), 12016. https://doi.org/10.1088/1742-6596/1013/1/012016
Nurhasanah, Z., Widodo, A., & Riandi, R. (2019). Augmented Reality to Facilitate Students' Biology Mastering Concepts and Digital Literacy. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *5*(3), 481–488. https://doi.org/10.22219/jpbi.v5i3.9694
Nursakinah, Y., Prima, E. C., & Agustin, R. R. (2023). The Development of FunLABS Android-Based Application Using Unity Software as Learning Media to Explore Students' Motivation on Acid, Base, and Salt Topic. *Journal of Science Learning*, *6*(2), 204–215. https://doi.org/10.17509/jsl.v6i2.50447
Nurseto, T. (2012). Membuat Media Pembelajaran yang Menarik. *Jurnal Ekonomi Dan Pendidikan*, *8*(1), 19–35. https://doi.org/10.21831/jep.v8i1.706
Pamoedji, A. K., Maryuni, & Sanjaya, R. (2017). *Mudah Membuat Game Augmented Reality (AR) dan Virtual Reality (VR) dengan Unity 3D* (4th ed.). PT. Elex Media Komputindo Kompas Gramedia.
Pierdicca, R., Frontoni, E., Zingaretti, P., Malinverni, E., Colosi, F., & Orazi, R. (2015). Making Visible the Invisible. Augmented Reality Visualization for 3D Reconstructions of Archaeological Sites. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *9254*, 25–37. https://doi.org/10.1007/978-3-319-22888-4
Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V, & Jackson, R. B. (2014). *Campbell Biology* (B. Wilbur, Ed.; 10th ed.).
Refirman, Sartono, N., & Hasanah, S. (2016). Pengaruh Learning Start with a Question (LSQ) terhadap Berpikir Analisis Siswa pada Materi Sistem Saraf. *Biosfer: Jurnal Pendidikan Biologi*, *9*(2), 6–13. http://journal.unj.ac.id/unj/index.php/biosfer/article/view/5577/4166
Reiser, R. A., & Gagné, R. M. (1982). Characteristics of Media Selection Models. *Review of Educational Research*, *52*(4), 499–512. https://doi.org/10.3102/00346543052004499
Reiss, M., & Tunnicliffe, S. (2001). What sorts of worlds do we live in nowadays? Teaching biology in a post-modern age. *Journal of Biological Education - J BIOL EDUC*, *35*, 125–129. https://doi.org/10.1080/00219266.2001.9655760
Rifa'i, M., Listyorini, T., & Latubessy, A. (2014). Penerapan Teknologi Augmented Reality pada Aplikasi Katalog Rumah Berbasis Android. *Prosiding Snatif*, 267–274. https://www.neliti.com/id/publications/174027/penerapan-teknologi-augmented-reality-pada-aplikasi-katalog-rumah-berbasis-andro
Rini, D. S., Azrai, E. P., Suryanda, A., Inayah, S. S., Khansa, A. A., & Kurnianto, M. B. (2022). Augmented reality (AR) technology on the android operating system in human respiratory system: From organ to cell. *Biosfer*, *15*(1), 25–35. https://doi.org/10.21009/biosferjpb.23448
Ristanto, R. H., Rusdi, Mahardika, R. D., Darmawan, E., & Ismirawati, N. (2020). Digital Flipbook Imunopedia (DFI) A Development in Immune System e-Learning Media. *International Journal of Interactive Mobile Technologies*, *14*(19), 140–162. https://doi.org/10.3991/ijim.v14i19.16795
Ristanto, R. H., Zubaidah, S., Amin, M., & Rohman, F. (2018). From a reader to a scientist: developing cirgi learning to empower scientific literacy and mastery of biology concept. *Biosfer*, *11*(2), 90–100. https://doi.org/10.21009/biosferjpb.v11n2.90-100
Ristanto, R. H., Zubaidah, S., Amin, M., & Rohman Fatchur. (2017). Scientific Literacy of Students Learned Through Guided Inquiry. *IJRR: International Journal Research and Review*, *4*(5), 23–30. https://www.ijrrjournal.com/IJRR_Vol.4_Issue.5_May2017/IJRR004.pdf
Rusdi, M. (2018). *Penelitian Desain dan Pengembangan Kependidikan* (1st ed.). Rajawali Pers.
Rusdi, R., Evriyani, D., & Praharsih, D. K. (2018). Pengaruh Model Pembelajaran Peer Instruction Flip Dan Flipped Classroom Terhadap Hasil Belajar Kognitif Siswa Pada Materi Sistem Ekskresi. *Biosfer:*

Jurnal Pendidikan Biologi, *9*(1), 15–19. https://doi.org/10.21009/biosferjpb.9-1.3
Rustaman, N., Dirdjosoemarto, S., Yudianto, S. A., Achmad, Y., Subekti, R., Rochintaniawati, D., & Nurjhani, M. (2005). *Strategi Belajar Mengajar Biologi*. UM Press.
Sadiman, A. S., Rahardjo, R., Haryono, A., & Harjito. (2014). *Media Pendidikan: Pengertian, Pengembangan, dan Pemanfaatannya* (S. Natakusumah, Ed.; 1st ed.). Pustekkom Dikbud dan PT Raja Grafindo Persada.
Sahertian, J., & Muladi. (2013). Pengembangan Media Pembelajaran Berbasis Teknologi Augmented Reality pada Pokok Bahasan Sel. *Tekno*, *19*, 9–14. http://journal.um.ac.id/index.php/tekno/article/view/4090
Sudarisman, S. (2015). Memahami Hakikat dan Karakteristik Pembelajaran Biologi dalam Upaya Menjawab Tantangan Abad 21 serta Optimalisasi Implementasi Kurikulum 2013. *Florea : Jurnal Biologi Dan Pembelajarannya*, *2*(1), 29–35. https://doi.org/10.25273/florea.v2i1.403
Sugiyono. (2015). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Alfabeta.
Sunarno, W., Adi, D., & Sukarmin, S. (2023). Learning science model based on Indonesia partnership for 21th century skills standard (IP21CSS). In *AIP Conference Proceedings* (Vol. 2540). https://doi.org/10.1063/5.0111751
Suryanda, A., Ernawati, E., & Maulana, A. (2018). Pengembangan Modul Multimedia Mobile Learning Dengan Android Studio 4.1 Materi Keanekaragaman Hayati Bagi Siswa Sma Kelas X. *Biosfer: Jurnal Pendidikan Biologi*, *9*(1), 55–64. https://doi.org/10.21009/biosferjpb.9-1.9
Tahyudin, I., Fitriyani, N. A., Dewiyanti, N., Amin, M. S., Firdaus, M. Y., & Utama, F. P. N. (2015). Inovasi Promosi Obyek Wisata Menggunakan Teknologi Augmented Teality (AR) Melalui Layar berbasis Android. *Jurnal Telematika*, *8*(1), 1–13. https://ejournal.amikompurwokerto.ac.id/index.php/telematika/article/view/259
Tegeh, I. M., Jampel, I. N., & Pudjawan, K. (2014). *Model Penelitian Pengembangan* (1st ed.). Graha Ilmu.
Tegeh, I. M., & Kirna, I. M. (2013). Pengembangan Bahan Ajar Metode Penelitian Pendidikan Dengan Addie Model. *Jurnal Ika*, *11*(1), 12–26. https://ejournal.undiksha.ac.id/index.php/IKA/article/view/1145/1008
Tsai, S.-T., & Chou, F.-H. (2023). Developing and testing a prototype smartphone educational application to address incivility and bullying in nursing workplaces. *Nurse Education Today*, *130*, 105925. https://doi.org/10.1016/j.nedt.2023.105925
Wardhono, W. S., Kusuma, L. P., & Marji, M. (2015). Evaluasi User Acceptance Augmented Reality Triage Mobile pada Sistem Kedaruratan Medis. *Seminar Teknologi Dan Rekayasa*, 978–979.
Wati, E. R. (2016). *Ragam Media Pembelajaran* (A. Jarot, Ed.). Kata Penas. www.solusibuku.com