Digestar: Augmented Reality-Based Learning Module as an Innovation in Human Digestive System Learning for 8th-grade junior high school students

Alvin Frenando[1*], Muhamad Daffa Septian[2], Afrillia Nur'Ajizah Azhar[3], Khusni Mubaroq[4], Abdul Karim[5]

[1]*Educational Management, Faculty of Education, Universitas Negeri Jakarta, Indonesia*

[2]*Sosiology Education, Faculty of Social Sciences and Law, Universitas Negeri Jakarta, Indonesia*

[3]*Guidance and Counselling, Faculty of Education, Universitas Negeri Jakarta, Indonesia*

[4]*Community Education, Faculty of Education, Universitas Negeri Jakarta, Indonesia*

[5]*Pancasila and Civic Education, Faculty of Social Science and Law, Universitas Negeri Jakarta, Indonesia*

ABSTRACT

The development of technology in education has encouraged various innovations, one of which is the use of digital learning media. Learning media play an important role in improving the quality of the teaching and learning process. Based on interviews with teachers at Junior High School 172 Jakarta, science subjects are still considered difficult and less interesting due to the limited use of innovative technology, especially in the topic of the human digestive system, which is difficult to understand without the support of interactive media. The results of a needs analysis conducted through questionnaires for eighth-grade students showed that 67.1% of students agreed that they had difficulties in understanding science materials, particularly the human digestive system, with 46.5% of students stating that the lack of interactive learning media was the main cause. Therefore, this study aims to develop an innovative learning medium, namely an Augmented Reality (AR)-based learning module on the topic of the human digestive system. This AR-based learning module is designed to help students learn more effectively and make the learning process more engaging and enjoyable. The development of the module applies the Research and Development (R&D) method using the 4D model (Define, Design, Develop, and Disseminate). The developed module was validated by material and media experts. Based on the validation results, the module obtained an average score of 95%, indicating that the AR-based learning module is highly feasible for use in learning activities. Furthermore, user testing conducted with eighth-grade students at Junior High School 172 Jakarta resulted in a score of 88%, showing that the module successfully made the learning process more interesting, interactive, and effective in helping students understand the concept of the human digestive system.

ABSTRAK

Perkembangan teknologi dalam pendidikan mendorong munculnya berbagai inovasi, salah satunya penggunaan media pembelajaran digital. Media pembelajaran berperan penting dalam meningkatkan kualitas proses belajar mengajar. Berdasarkan wawancara dengan guru di SMP Negeri 172 Jakarta, mata pelajaran IPA masih dianggap sulit dan kurang diminati karena minimnya penerapan teknologi inovatif, terutama pada materi sistem pencernaan manusia yang sulit dipahami tanpa dukungan media interaktif. Hasil analisis kebutuhan melalui angket kepada siswa kelas VIII menunjukkan bahwa 67,1% siswa setuju bahwa mereka mengalami kesulitan dalam memahami materi IPA, khususnya sistem pencernaan manusia, dengan 46,5% siswa menyatakan kurangnya media pembelajaran interaktif sebagai penyebab utama. Oleh karena itu, penelitian ini bertujuan untuk mengembangkan sebuah media pembelajaran inovatif, yaitu modul berbasis *Augmented Reality* (AR) pada materi sistem pencernaan manusia. Modul pembelajaran berbasis AR ini ditujukan untuk membantu siswa dalam pembelajaran dan membuat kegiatan belajar mengajar menjadi lebih menarik dan menyenangkan. Pengembangan modul berbasis AR menerapkan metode *Research and Development* dengan model 4D (*Define, Design, Development, Disseminate*). Modul pembelajaran yang dikembangkan telah divalidasi melalui uji ahli materi dan media. Berdasarkan hasil uji validasi oleh para ahli, rata-rata yang didapatkan adalah sebesar 95% yang menunjukkan modul pembelajaran berbasis AR ini sangat layak digunakan. Kemudian, berdasarkan hasil uji coba pengguna kepada siswa kelas VIII-1 SMP Negeri 172 Jakarta, data yang diperoleh adalah sebesar 88% yang menunjukkan bahwa modul pembelajaran mampu membuat proses pembelajaran menjadi lebih menarik, interaktif, dan membantu siswa memahami konsep sistem pencernaan manusia dengan lebih jelas.

CONTACT

alvin.frenando@gmail.com

KEYWORDS

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INTRODUCTION

Agricultural development currently plays a strategic role in supporting food security. However, Indonesia continues to face several major challenges that hinder sustainable agricultural development. One of the most significant issues is the continuous reduction of agricultural land. According to Anton Apriyantono, there are five major land-related problems in Indonesia. First, farmers own relatively small plots of land, making it difficult to support their families' livelihoods. Second, land productivity continues to decline due to excessive intensification and the prolonged use of chemical fertilizers. Third, agricultural land conversion to non-agricultural purposes, such as industrial development and residential areas, has increased significantly. Fourth, the implementation of commodity mapping based on agroecosystems has not yet been optimized. Fifth, a considerable amount of land remains idle and unutilized (Anton Apriyantono, *Agricultural Development in Indonesia*, p. 13).

The world of education continues to undergo change in line with rapidly advancing technology. Technological development in the digital era is unavoidable and influences all aspects, especially education (Sadriani, et al., 2023). Education must be able to follow technological progress in order to realize quality education. By keeping pace with the times, education will be able to provide learning innovations that are relevant and no longer focused solely on books or blackboards, but on media that are more engaging, interactive, and in accordance with contemporary developments (Wibowo, 2023). Learning innovations and strategies are both a solution and an important role that can improve the quality of education in Indonesia in teaching and learning activities (Styana & Nurhidayati, 2024).

One of the actions carried out in the classroom to achieve desired outcomes is teaching and learning activities (Hasan et al., 2021). One of the most important factors that can facilitate learning activities is the use of educational media. The selection of appropriate teaching materials is crucial to help students understand the material studied in class. According to Masdar et al. (2024), the use of appropriate educational resources can increase students' enthusiasm for the learning process, facilitate their understanding of lesson material, and contribute to the development of a more efficient and engaging teaching and learning environment.

Natural Science is one of many academic fields that can benefit from the use of innovative and engaging learning materials. Natural science itself is a compulsory subject in junior high school. According to Fitriana et al. (2024), natural science is a fairly complex subject that requires students to understand various scientific concepts, perform calculations, memorize formulas, and observe natural phenomena and their environment. Some students claim that natural science is often considered a difficult topic because it contains scientific and Latin terms that are difficult to remember and understand, as well as abstract concepts (Ndruru, 2023).

This is evidenced by the results of the Programme for International Student Assessment (PISA) survey (2022) released by the Organisation for Economic Cooperation and Development (OECD), which show that the average science score reached 383 points compared with the OECD country average of 485 points. Furthermore, 34.16% in the field of science indicates that Indonesia is still far behind compared to the OECD country average, which ranges from 68% to 75%. This significant difference shows a considerable gap in the quality of science learning, both in terms of curriculum, methods, learning media, and student engagement in learning. This fact can serve as an evaluation for education in Indonesia regarding science learning strategies that require solutions capable of encouraging students' understanding of natural science.

According to an interview with a teacher at Junior High School 172 Jakarta, students still experience difficulties in science subjects and have low interest. One subject that is often difficult for students to understand is the human digestive system. This is partly caused by a lack of up-to-date digital technology that is compatible with the modern world and can increase students' learning motivation. At that school, technology use is limited to PowerPoint or YouTube videos to support learning. Therefore, to maintain students' interest during the learning process, creative and digital learning materials are required. Students will learn more effectively and benefit from the use of such learning resources.

Furthermore, based on the needs analysis questionnaire results of grade 8th students at Junior High School 172 Jakarta, 67.1% agreed and 9% strongly agreed that students experience difficulty understanding science subjects, and students mentioned that "Structure and Function of Living Organisms," specifically the Human Digestive System, is one of the most difficult topics they study. This is caused by the limited availability of interactive learning media found in the questionnaire results, at 46.5%. This is reinforced by Sari and Tenriawaru (2023), who reported that from interviews with 10 students, 7 students did not like the human digestive system material and 8 students considered the material difficult.

In addition, 31.6% of students strongly agreed and 67.1% agreed that new learning media are needed to improve science instruction. Putri et al. (2022) found that interactive learning materials can increase student learning outcomes by engaging the five senses, which encourages better understanding throughout the learning

process. Students most prefer learning materials that are interactive (clickable, movable, playable), visually appealing (color, graphics, animation), and accessible in 3D or Augmented Reality (AR) (Putri, et al., 2022). Therefore, it can be said that to improve their understanding and support their science learning, students need access to supportive educational learning materials.

Given this condition, students need a solution that can address their needs in learning media, namely technology integrated with Augmented Reality (AR). AR is a technology that combines real objects with digital images or animations, allowing users to see and experience both simultaneously (Indahsari & Sumirat, 2023). AR is a solution that can be used in various engaging learning media (Rojib & Ratnawati, 2023). The use of AR in modules is an innovative learning medium that can be applied in instruction.

Based on this background, the researchers used Augmented Reality (AR) technology to create more dynamic and engaging learning materials as a solution. This innovation is packaged in a study entitled "Digestar: Augmented Reality-Based Learning Module as an Innovation in Human Digestive System Learning for 8th-grade junior high school students". By enabling students to directly experience learning content through realistic 3D simulations, AR will provide a fresh, dynamic, and engaging educational experience that will enhance their understanding of science subjects. With this innovation, it is expected that 8th-grade students of Junir High School 172 Jakarta can identify, understand, and improve their science knowledge on the human digestive system material and that it can serve as a learning.

METHODS

In this study, the approach applied was Research and Development (R&D). According to Sugiyono (2023), the R&D method is a research approach that begins with a needs analysis to produce a product. The development model applied in this study was the 4D (Define, Design, Develop, Disseminate). This model was chosen as a reference in the product development process because it has systematic stages, from defining needs, designing, developing, to disseminating the product.

At the define stage, the main activities carried out were analyzing the needs for developing an Augmented Reality (AR)-based learning module through needs analysis, interviews with teachers, distribution of instruments to students, and literature study to identify learning problems, student characteristics, curriculum, and the initial specifications of the product to be developed. The design stage was conducted by composing the structure and content of the module, designing AR-based visual and interactive components, creating an initial prototype, determining visual style, text layout, icons, and symbols that support ease of use, and preparing hardware and software including Canva Premium, Hyper3D, Assemblr EDU. Next, in the develop stage, the researchers developed the AR-based learning module according to the prepared design, then conducted validation by media experts and material experts to assess the feasibility of the content, appearance, and interactivity of the module, and made revisions based on the feedback provided so that the resulting product became more effective, attractive, and easy to use. The final stage, disseminate, was carried out by implementing the module in a field trial to document the process of use, student interactions, and technical constraints that emerged. In addition, in this stage data were collected through teacher and student response questionnaires as user tests to obtain feedback regarding ease of use, quality, and usefulness of the AR-based learning module (Cahyanto et al., 2024).

Data collection in this study was divided into two categories: needs analysis data and learning media development data. Needs analysis data were collected at the define stage to determine the learning conditions, problems faced, and the needs for developing the AR-based Digestar module. These data were obtained through interviews with science teachers and the distribution of a needs analysis questionnaire to grade 8th students. The results of this needs analysis served as the basis for the module development process.

Next, the learning media development data were collected to determine the feasibility of the developed Digestar module. Data were obtained through questionnaires administered to media experts, material experts, and students as users. These questionnaires were used to assess aspects of content, appearance, interactivity, ease of use, and usefulness of the module. The assessment results were then analyzed using a Likert scale to determine the level of feasibility of the Digestar module as a learning medium.

Data analysis in this study used descriptive statistics to describe the obtained assessment results without making generalizations (Sugiyono, 2023). Data were collected using a 4-point Likert scale questionnaire, i.e., scores 1–4, to assess the feasibility of the learning media. The use of four answer choices aims to avoid respondents' tendency to choose a neutral response (Sugiyono, 2023).

Table 1. Expert and User Assessment Scores

Description	Scor
Completely Not Feasible	1
Not Feasible	2
Feasible	3
Highly Feasible	4

(Sugiyono, 2023)

Each testing stage used different assessment indicators according to the objectives of the evaluation. Material validation consisted of 15 indicators covering three aspects, namely content feasibility, linguistic quality, and presentation feasibility. Media validation used 16 indicators divided into four aspects, namely visual attractiveness, media practicality, media readability, and media readiness. Meanwhile, the user test involved 11 indicators grouped into three aspects, namely media attractiveness, ease of use, and comprehensibility of the material as filled out by students. All obtained scores were then analyzed in percentage form to determine the feasibility level of the Digestar module based on the established percentage criteria.

Table 2. Feasibility Criteria Based on Percentage

No	Quality Score	Feasibility Category
1	0% - 25%	Highly Infeasible
2	26% - 50%	Not Feasible
3	51% - 75%	Feasible
4	76% - 100%	Highly Feasible

(Sugiyono, 2023)

The assessment data from media experts, content experts, and user testing were analyzed by calculating the percentage of the feasibility score using the following formula (Sugiyono, 2023).

Formula for average score:

$$\text{Average score} = \frac{\text{data collection scores}}{\text{maximum score}} \; x \; 100\%$$

Source: (Sugiyono, 2023)

RESULTS AND DISCUSSIONS

During data collection the first activity undertaken was Define (Definition); this stage was conducted to analyze needs through field study and literature review. Data were collected via interviews and needs analysis (questionnaires distributed to students). Interviews were conducted with the teacher responsible for the Natural Sciences subject at Junior High School 172 Jakarta. The interviews revealed that the school experienced difficulties in understanding Structure and Function of Living Things, particularly the Human Digestive System material. It was also found that the school had never created Augmented Reality (AR)-based learning media aligned with the school textbook and with materials that were duplicated.

Next, questionnaires in the form of Google Forms were distributed to eighth-grade students using two different questionnaires: one for analysis of content and media needs, and one for AR needs analysis. The questionnaire results showed that students indeed experienced difficulties in natural science, particularly the Human Digestive System, which was perceived as difficult and in need of interactive and visually appealing media. Emphasized by the AR needs questionnaire, students expressed a need for learning media based on current technology, such as AR. Thus, students agreed that AR learning media are positive and that they need them in instruction.

A literature study was conducted on the analysis of student needs and the curriculum. The student analysis was performed to obtain an overview of students' needs, difficulties, and conditions in the learning process. The results of this analysis were used as a basis for determining learning media that match students' needs and can facilitate the learning process. Curriculum analysis was conducted to ensure that the developed learning module aligns with the direction and demands of the Merdeka Curriculum, particularly for natural science at the junior high school Phase D level. All curriculum analyses referred to the Capaian Pembelajaran (CP) document of Kemendikbudristek (2022); the curriculum analysis indicated alignment among curriculum goals, learning needs, and the product innovation developed.

The Design stage focused on designing the learning media to be developed. This activity included gathering reference teaching materials, composing the interface concept and usage flow, selecting content/material, formulating a flowchart, creating design guidelines, and strategizing presentation of the material to suit student characteristics. At this stage, aspects such as students' learning styles and the most effective instructional approaches

to support optimal use of the media were also considered.

In the Product Development stage, the Digestar learning module was developed from the module according to the initial design, adding contextual text, images, and AR markers that can be scanned using the Assemblr Edu application to display the human digestive organs, and finally incorporating the validation results from media and content experts. Thus, this stage represents product completion, in which Digestar was finalized and no further revisions were made by the developer or validators. The following are the final results of the Digestar learning module as learning media for grade 8th students. Below are the Digestar media displays, from the opening page to the available features:



Figure 1. Cover



Figure 2. List Of Contents Digestar



Figure 3. General Information on Digestar Teaching Tools and Learning Objectives



Figure 4. Material or Content

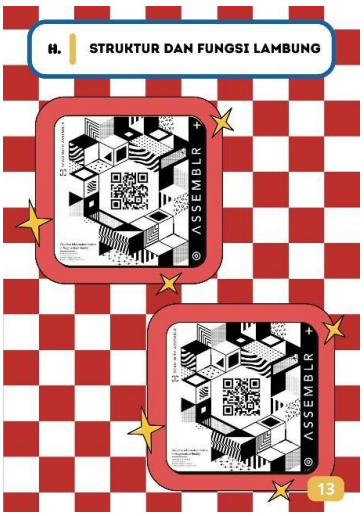


Figure 5. AR Marker View

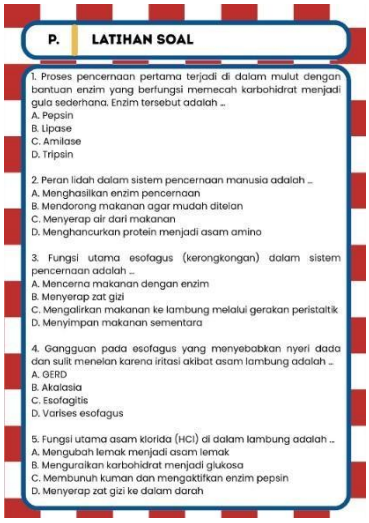


Figure 6. Digestar Practice Questions



Figure 7. Brief Description of Digestar

The results of the media and content validation tests were categorized as "Very Feasible" and, after expert review, revisions were made in accordance with suggestions and input. The following are the validation results by the content and media experts, presented in the table below:

Table 3. Results of Expert Validation

Assessment Aspects	Average Score	Percentage of Achievement	Feasibility Category
Media & Language Expert Assessment	3.8	95%	Highly Feasible
Subject Matter Expert Assessment	3.7	93%	Highly Feasible
	Overall Average	**94%**	**Highly Feasible**

After obtaining expert validation results in the Very Feasible category, Digestar proceeded to conduct user testing with students. Digestar was trialed with grade 8th students at Junior High School 172 Jakarta with 34 respondents. Students were given a questionnaire via Google Forms with 11 questions or indicators. The following are the results of user testing of grade 8th students at Junior High School 172 Jakarta:

Table 4. Results of User Testing

No	Indicator	Average	Percentage	Category
1	The learning media display (images and AR animations) is highly visually appealing.	3,6	90%	Highly Feasible
2	The learning media makes learning more enjoyable.	3,7	94%	Highly Feasible
3	The AR feature in the media is engaging and helps in learning the human digestive system.	3,5	88%	Highly Feasible
4	The presentation of the learning media is attractive and supports the learning process.	3,8	95%	Highly Feasible
5	The learning media is easy to access and use.	3,3	83%	Highly Feasible
6	The learning media operated well without any issues.	3,2	81%	Highly Feasible

7	The learning media can facilitate learning anywhere with flexible scheduling.	3,5	89%	Highly Feasible
8	The human digestive system material in the learning media is consistent with natural science instruction in schools.	3,5	88%	Highly Feasible
9	The information and material in the learning media are presented clearly and are easy to understand.	3,5	87%	Highly Feasible
10	The learning media can help in understanding the human digestive system.	3,6	91%	Highly Feasible
11	The AR feature facilitates remembering the parts of the human digestive system.	3,6	90%	Highly Feasible
	Average	**3,5**	**88%**	Highly Feasible

The development of the Augmented Reality (AR)-based module originated from the condition that students still experienced difficulties in understanding natural science material, specifically the human digestive system. Previously used learning media were limited, so a more interactive medium that could provide a concrete representation of the material was required. This need was implemented in a module that not only contains material, images, and practice questions, but is also equipped with an AR feature to display the digestive system organs in three dimensions. Through this feature, students can observe the shape and position of organs more realistically, allowing material that was previously difficult to visualize to be learned in a way that is easier to explore.

In terms of content and language, the module obtained a feasibility percentage of 93% with the category Very Feasible. This assessment covered the alignment of the material with natural science instruction, conceptual accuracy, completeness of material, language use, and the relationship between the material and AR visualization. Some suggestions from experts were used to improve terminology, concept presentation, information regarding digestive system disorders, and example questions. These improvements were made so that the material presented would be more accurate, complete, and appropriate to the comprehension level of junior high school students.

From the media perspective, the product received a percentage of 95% with the category Very Feasible. Media expert assessment included visual appearance, readability, practicality, and the media's readiness for classroom use. These scores indicate that the arrangement of visual elements, module appearance, and integration of AR features met the established criteria. Combined with the validation results from content and language experts, the average expert assessment reached 94%, so the product was deemed very feasible for use in the student trial stage.

The use of the module by class 8th-1 at Junior High Schol 172 Jakarta yielded a percentage of 88% in the Very Feasible category. Students gave positive responses to the presentation of digestive system organs in three dimensions because it allowed the material to be observed differently from previous instruction. The module was also considered easy to use via mobile phone and provided a more flexible learning experience. These responses indicate that the product is acceptable to users and aligns with students' needs for more interactive learning media.

The findings of this module development are consistent with Aini et al. (2025), who stated that AR-based media can help students understand abstract concepts in natural science while making learning more enjoyable. Alfiani et al. (2024) also developed AR-based media on the human digestive system material. The similarity is evident in the use of AR technology and the developed content, while the difference lies in the product form because this study produced a module that uses a QR code to access the AR display. This study also parallels Syavira (2021), who developed interactive learning media on the human digestive system material, but the media used there were interactive PowerPoint with a different development model.

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Utilization of the AR-based module can provide variety in the natural science learning process, especially when

the teacher delivers material that requires visualization. Students can observe digestive system organs through three-dimensional objects, while teachers can use the module as a supplementary medium to explain the material. Interaction with those objects also supports the constructivist approach that underpinned the development, since students do not only receive information through text but also build understanding through experience and exploration.

The development of this module provides an alternative application of AR technology in natural science instructional media by integrating a module-format textbook with three-dimensional visualizations. The resulting product not only contains material and practice exercises but also offers students the opportunity to observe learning objects more concretely. The use of QR codes as links to the AR feature also allows this technology to be incorporated as part of the module without altering the overall form of the teaching material. From a development perspective, the 4D model facilitates a staged product construction process, beginning with needs analysis, followed by design, development, and dissemination.

Although the results obtained are highly feasible, there are several limitations in this study. Product trials were conducted in only one class, namely class 8th-1 at Junior High School 172 Jakarta, so the results do not yet represent the use of the module among students with different school characteristics. The use of the AR feature also requires devices that support the Assemblr Edu application and a stable internet connection. In addition, the developed AR feature is still limited to three-dimensional models of digestive organs without added motion animations or explanatory audio.

These conditions can be considered for subsequent research development. Trials can be expanded by involving more students and schools so that the product's use can be observed under more diverse conditions. The AR feature can also be further developed by adding animations, voice narration, and interactive quizzes. Future research can also test the module's effectiveness on student learning outcomes more deeply so that the product's benefits are assessed not only by feasibility and user responses but also by the learning outcomes achieved.

Overall, the Augmented Reality-based module on the human digestive system material obtained results categorized as Very Feasible from various parties involved in testing. Content and language expert validation reached 93%, media expert validation reached 95%, with an overall average validation of 94%, while student responses reached 88%. This product can be used as an alternative natural science learning medium that combines material presentation with three-dimensional visualization so that learning about the human digestive system becomes more interactive, concrete, and aligned with students' needs.

CONCLUSIONS

The development of an Augmented Reality (AR)-based learning module on the human digestive system for eighth-grade students at Junior High School 172 Jakarta produced a learning medium categorized as Very Feasible. Content and language expert validation yielded a percentage of 93%, media expert validation yielded 95%, with an overall average validation reaching 94%. Student responses also obtained a result of 88%, categorized as Very Feasible. The use of AR through three-dimensional visualization can provide a more interactive learning experience and help students understand the digestive system organs more concretely. The developed module can serve as an alternative natural science learning medium that integrates instructional materials with technology in accordance with students' needs.

Subsequent development is recommended to involve more students and schools so the product can be tested on users with more diverse characteristics. The AR feature can also be developed by adding animations, audio, and interactive quizzes to make the learning experience more varied. In addition, future research can examine the module's effectiveness on student learning outcomes more deeply, not only based on feasibility and user responses. The availability of devices and internet connectivity should also be considered so that the AR feature can be used optimally in instruction.

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