Edcomtech: Jurnal Kajian Teknologi Pendidikan
Vol 9, No 1, April 2024, pp. 41-57
https://doi.org/10.17977/um039v9i12024p41
pISSN: 2548-9879 (print) eISSN: 2599-2139 (online)
http://journal2.um.ac.id/index.php/edcomtech

Development of Interactive Web-Based Augmented Reality for Human Digestive System in Class XI

Yanuar Rizky[1], Ence Surahman[2], Made Duananda Kartika[3]

[1,2,3] *Teknologi Pendidikan, Universitas Negeri Malang, Jalan Semarang 5 Malang, Jawa Timur, Indonesia 65145*
Author:* yanuar.rizky.2101216@students.um.ac.id

Article Info
Article history:
Received 30-03-2024
Revised 20-06-2024
Accepted 11-07-2024
Published 12-07-2024

How to cite:
Rizky, Y., Surahman, E., & Degeng, M. D. K. (2024). Development of Interactive Web-Based Augmented Reality for Human Digestive System in Class XI. *Edcomtech: Jurnal Kajian Teknologi Pendidikan*, 9(1), 41–57. https://doi.org/10.17977/um039v9i12024p41

Abstrak

Penelitian ini bertujuan untuk mengembangkan media pembelajaran interaktif berbasis Augmented Reality (AR) berbasis web dalam pengajaran sistem pencernaan manusia bagi siswa Biologi kelas XI, dengan mengatasi keterbatasan praktis dari media berbasis aplikasi. Tujuan utama pengembangan ini adalah meningkatkan keterlibatan siswa, visualisasi materi, dan hasil belajar tanpa memerlukan instalasi aplikasi tambahan. Penelitian ini mengikuti model pengembangan Sadiman, yang melibatkan tujuh tahap mulai dari analisis kebutuhan hingga pengujian produk. Hasil validasi oleh ahli materi dan media menunjukkan bahwa media yang dikembangkan sangat efektif dan layak digunakan di kelas. Uji coba dilakukan pada kelompok kecil yang terdiri dari lima siswa serta uji lapangan dengan melibatkan 30 siswa. Hasil uji lapangan menunjukkan peningkatan hasil belajar yang signifikan dengan rata-rata peningkatan sebesar 20,70%. Selain itu, hasil kuesioner menunjukkan tingkat persetujuan sebesar 83,41%, yang mengindikasikan bahwa siswa merasa media ini efektif dalam memahami konsep-konsep abstrak. Kesimpulannya, media pembelajaran interaktif berbasis AR berbasis web ini terbukti efektif dalam meningkatkan hasil belajar dan minat siswa terhadap Biologi. Media ini tidak hanya menjadi alat yang bernilai dalam meningkatkan kualitas pendidikan, tetapi juga dapat menjadi model dalam pengembangan sumber belajar berbasis teknologi kedepannya.

Kata Kunci: *Augmented Reality, Biologi, website, Media Pembelajaran Digital*

Abstract

This study aims to develop interactive, web-based augmented reality (AR) learning media for teaching the human digestive system to 11th-grade Biology students, addressing the practical limitations of application-based media. The goal is to enhance student engagement, material visualization, and learning outcomes without requiring additional app installations. The research followed the Sadiman development model, involving seven stages from needs analysis to product testing. Validation results for content and media indicated that the developed media is highly effective and suitable for use in the classroom. Trials were conducted with a small group of five students and a field test involving 30 students. The field test results showed a

significant improvement in learning outcomes, with an average increase of 20.70%. Additionally, questionnaires revealed an approval rate of 83.41%, indicating that students found the media effective in understanding abstract concepts. In conclusion, the interactive, web-based AR learning media proved effective in improving students' learning outcomes and interest in Biology. This media not only offers a valuable tool for enhancing education but also serves as a model for the development of future technology-based learning resources.

Keywords: *Augmented Reality, Biology, website, digital learning media*

INTRODUCTION

Instructional media are designed to assist students in learning; therefore, their development should also consider attractiveness to enhance students' learning interest and facilitate independent study. Specifically, for complex topics such as the human digestive system, the use of ineffective media like textbooks and 2D images often fails to help students grasp intricate concepts such as human anatomy. Physical media, such as mannequins, can aid visualization; however, such resources are not easily accessible to every student or suitable for independent learning. Utami & Murti (2018) argue that traditional teaching methods and media are often ineffective in helping students comprehend complex topics. One of the digital media innovations for biology education is augmented reality (AR), which can enhance visualization for students (Akçayır, 2017). Beyond improving students' understanding, interactive learning media such as AR can also boost engagement and enthusiasm in learning activities (Carolina, 2022). At SMAN Rambipuji, the research setting, the author found that the use of biology learning media is limited to non-digital resources (books and mannequins). Additionally, the limited availability of physical media often results in learning activities relying solely on textbooks.

Responding to these field conditions, one potential development plan is augmented reality, which, according to Supriyadi et al., (2022), has been shown to enhance student engagement in education through observational activities, thereby improving their understanding. However, the use of augmented reality also presents challenges in terms of accessibility, particularly when technological resources are limited or students' devices are incompatible (Anggraeni & Ekohariadi, 2024). This aligns with the findings of Alqurashi (2019), whose research identified obstacles in using mobile applications, including storage limitations, inadequate minimum specifications, or other factors that hinder usability.

Given the challenges faced in the field alongside the barriers identified in previous studies, this research seeks to formulate a more accessible medium of learning whilst still maintaining a focus on interactive multimedia, specifically in terms of visualising more complex topics. Based on the research of Ioannou et al., (2015), showed that using both visual and verbal elements could support students learning. Additionally, Putra et al,. (2021) emphasize that a good understanding of underlying topics prepares the ground for learning biological concepts. Captivating all forms of online media, web-based media can be retrieved without the download of any new application on a selected device. This is in line with its application in a variety of learning contexts, including schools as well as the home, where it can be used easily and effectively. Web-based AR technology also allows for self-directed learning. Students can explore the material independently without relying solely on educators thanks to user-friendly navigation features and clear usage instructions. This is a device that has interactive

infographics, mixing text images and animation to explain concepts of biology. This method accomplishes that for students with visual and kinesthetic learning styles.

Past research created AR media use for the human digestion system. Nevertheless, most rely on Android applications and marker-based tracking techniques. (Riyanto & Jollyta, 2023) and (Cahyaningrum et al., 2022) showed that Android-based augmented reality can improve students' educational performance and motivation, but its effectiveness is constrained by the requirement of installing extra applications. Moreover, (Gunawan, 2023) highlights points out that costs, lack of devices and user readiness are additional barriers for widespread use of AR in education. These barriers highlight that while AR has the potential of enhancing the learning experience through interactive visualization, technical and theoretically accessibility limitations are still major challenges. To overcome the gap between the effective use of AR but hampered by the limitations of AR devices, thus this research is to create an interactive without the need of installation processes that compromise the burdened of devices, AR features integrated web-based learning media. Additionally, this web-based approach allows for integration with other digital resources to support learning activities on the human digestive system for Grade XI students. This study adopts the dual coding principle as the grand theory in the development of interactive multimedia learning media, utilizing a combination of visual and verbal elements in content delivery to enhance students' understanding through information processing and retention. The primary contribution of this research is the development of a practical and inclusive learning medium. Unlike mobile applications, web-based platforms eliminate common technical constraints, making them a solution that addresses previous challenges in educational technology innovation.

MENTHOD

This study employs the Sadiman (2018) development model, which consists of eight structured stages. The first stage begins with a needs analysis, where the researcher identifies challenges in learning the human digestive system and the limitations of existing media at SMAN Rambipuji through direct observations and interviews with students and teachers. The second stage involves formulating objectives, setting specific targets to enhance the understanding of Grade XI students on the human digestive system topic. The third stage focuses on content development and material adaptation based on the applicable curriculum, including the preparation of text/narration within the media, UI/UX design, and 3D model development. Then it is followed by developing assessment tools, including pre-tests, post-tests, and questionnaires that are meant to measure media effectiveness and user experience. The media script writing stage involves developing the UI and navigation and integrating text, images, animations, and 3D objects in accordance with multimedia principles. It is then combined into an interactive web-based platform in the production phase. After being developed, it takes place on a small group to allow the student to try out for content readability, ease of use, and media effective. Training on data only until October 2023, these trial results help inform the revision and refinement phase, improving both the design and functionality before scaling.

Once approved, the instructional media then tried the research sample, namely class XI students at SMAN Rambipuji. The reason for the selection was the relevance of the digestive system subject matter in the 11th-grade curriculum, and the students' current readiness to implement web-based technology. The trial was carried out in stages, starting with a small-group trial of five students to determine content readability and ease of navigation. The initial users: After implementing feedback, we conducted a field trial with 30 students taking the

same class. This phase (application) in which the effectiveness of the media can be assessed by comparing the results of pre-test and post-test and collecting data from questionnaires regarding student responses to the implementation of learning. By using this method, the researcher became able to assess the role of the media on students' comprehension, as well as how far it could actually improve their educational achievements.

To guarantee the appropriateness of the learning media which are obtained by accessibility searching media during the educational process, and gather content & media validation by experts both from a biology teacher of SMAN Rambipuji & an educational technology lecturer. Following the development of media and materials, an expert validation is conducted to evaluate content and media design in terms of their adequacy for the learning process. The assessment framework for validation in this step refers to the guidelines of Arikunto (2010) that classify materials as "feasible" and media as "effective." There are four sub criteria, according to Arikunto, levels of feasibility and effectiveness: Feasible/Effective (with 81%-100%), Moderately Feasible/Effective (61%-80%), Less Feasible/Effective (41%-60%), and Not Feasible/Effective (<40%). Such expert validation generates clear quantitative data on both learning outcomes and user experience with media use and allows much more direct comparisons to similar studies conducted applying the same evaluative standards.

Statistically analyze the effectiveness of the learning media and its effect on the learning outcomes using Paired Sample T-Test and measuring effect size with Cohen's D Test. Effect size interpretation that classifies Effect Size (ES) into six levels: (1) Negligible (0.00≤ES<0.20); (2) Small (0.20≤ES<0.50); (3) Medium (0.50≤ES<0.80); (4) Large (0.80≤ES<1.30); (5) Very Large (1.30≤ES; and (6) Extremely Large (2≤ES). In addition, Cohen's D test divides the effect size into different ranges, which are: (1) Very Small Effect (0.01≤|d|<0.2); (2) Small Effect (0.02≤|d|<0.5); (3) Medium Effect (0.05≤|d|<0.8); (4) Large Effect (0.08≤|d|<1.2); (5) Very Large Effect (1.2≤|d|<2); and (6) Extremely Large Effect (|d|≥2) (Cohen, 1988). This analytical approach is encouraging a more in dept evaluation of the worthiness of the learning media by its betterment and contribution of its worth on streamlining student learning outcomes.

RESULT

Development Media

Multimodal AR media (or format of interactive web-based media) was produced for the human digestive system topic. The content here is broken into four sections, representing the stages of the digestive system, to facilitate learning for students. The mouth and esophagus are the first stage, outlining the first phase of digestion, mechanical and chemical, along with the organs before food hits the stomach. In the next phase, you learn about how the stomach processes food using digestive enzymes and gastric acids. Stage 3 examines the small intestine, where most nutrient absorption takes place. In the last stage, Stage 4 refers to the large intestine and anus, representing water absorption and waste excretion. Following all the stages that are extracted from the book "Buku Ajar Anatomi Fisiologi dan Gangguan Sistem Pencernaan" Susilawati (2018) and article Human digestive system: Structure and function Hasan & Widodo (2018) which has been aligned with school curriculum. The media structure can help students visualize each portion of the digestive system to see how the biological systems work and align themselves with educational standards. This instructional media while leveraging AR not only keeps them engaged but also helps students in visualizing abstract concepts pertaining to human biology. We began to create three-dimensional (3D) models of digestive organs in Blender, paying particular attention to texture realism and length scaling. The 3D model design for each material is saved in. obj format. An embed code

is created by the Assembler Studio platform for adding these models to the site. The visual bits are created on Canva as crucial blocks, and Google Sites is used to build a light-weight, responsive landing page that is mobile friendly.

This human digestive system learning media is made with 3D visualization content, the students can see objects by rotating or zooming out each organ and read the material. Alongside each organ, a descriptive narrative explains its structure, function and how it works within the body. Media via bit Students showing their creativity and wit.ly //smara-digestive, which then points them to the media's homepage.

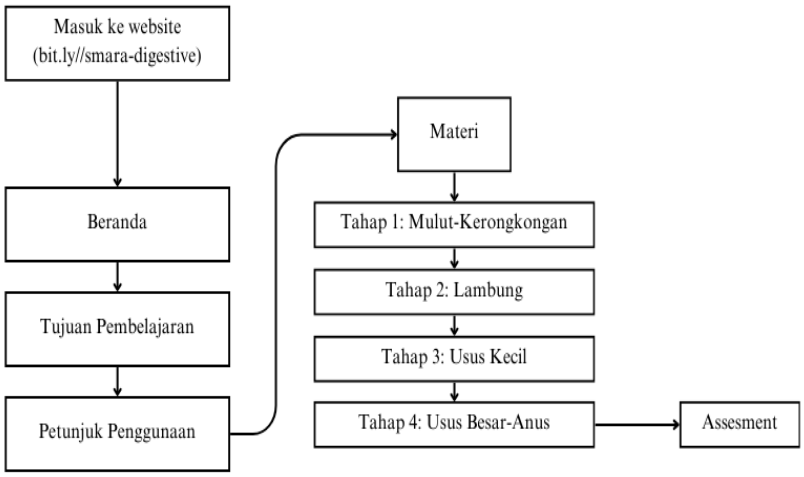

Figure 1. Media Usage Flow

Table 1. Media Design

No	Visual	Information
1		If students click on the provided link they will be directed to the first page that includes user guidelines, learning objectives, and a structured flow for learning. So that students have time to get used to the platform before diving into the material themselves.
2		Students click on a topic on the homepage, where there are four stage of the human digestive system. They can also directly choose any topic instead of starting from stage 1, which makes it easier to finish their learning or show information that requires them to review or learn more.

No	Visual	Information
3		A page explaining the learning objectives.
4		A page providing usage instructions through a YouTube video, as well as the minimum device specifications for both smartphones and computers.
5		Stage 1: Mouth – Esophagus The mouth exists as a series of 3D models, illustrations of muscle movement, and precise anatomical structures. The voiceover provides a step-by-step explanation of functions of each part, along with the physiological procedures behind them. The media is interactive, enabling students to click on specific components for elaborate explanations, and use zoom-in, zoom-out, and rotation features to dissect the 3D visualization from different angles.
6		Stage 2: Stomach This segment features a 3D design and also corresponding text for every stomach component, including its secreting digestive enzymes and breaking in the stomach. Its media is to be interactive as students can pick particular parts for elaborated explanations and also they can use zoom in, zoom out, and rotation functionalities to see 3D visualization's angles.
7		Stage 3: Small Intestine;This phase in the digestive system is presented in the form of 3D representations and written explanations of the digestion occuring in the small intestine. Along with studying the functions and structures of this organ, students learn about disorders involving their health that are related to digestion. This media is also interactive, enabling students to click parts that need a more detailed explanation, while also providing zoom in and out, and rotating options in order to look at and through the 3D visualization from different angles.

No	Visual	Information
8		Stage 4: Large Intestine and Anus;Here students will learn about the anatomy and physiology and diseases related to the large intestine and anus. Next, this media is interactive, so students can click on parts they wish to know more about, and use zoom-in, zoom-out, and rotating options to observe the 3D visualization from various angles.

The The validation results from content experts indicate a total score of 76 out of 80. The assessment covered three aspects: relevance, usability, and ease of use. Relevance received excellent evaluations for its alignment with student competencies, curriculum accuracy, and adherence to linguistic norms. Usability was rated highly due to the effectiveness of interactive infographics in enhancing understanding, motivation, and independent learning. For ease of use, the infographic-based materials were considered intuitive, simplifying students' exploration and achievement of learning objectives.

The feasibility percentage was calculated using the formula by (Abdullah & Rery, 2022):

$$Feasibility\ Percentage = \frac{Total\ Score}{Maximum\ Score} x100\%$$

Substitution of the resulting score values:

$$Feasibility\ Percentage = \frac{76}{80} x100\%$$

$$= 95\%$$

According to Arikunto (2010), this percentage falls within the "Feasible" category (81%-100%), indicating that the developed media is highly suitable as a learning resource. Similarly, the media expert validation yielded a total score of 79 out of 80, assessing quality, attractiveness, and ease of use. The media's quality received strong ratings for its simple operation, seamless integration of text, images, and videos, and a harmonious color scheme. The interactive infographic design was praised for its engaging visual elements that enhance material presentation. Additionally, the media demonstrated clear navigation, easily understood instructions, and high usability without requiring specialized skills.

.

The eligibility percentage is calculated using the formula by (Abdullah & Rery, 2022):

$$Feasibility\ Percentage = \frac{Total\ Score}{Maximum\ Score} x100\%$$

With score substitution we get:

$$Feasibility\ Percentage = \frac{79}{80} x100\%$$

$$= 98{,}75 \approx 99\%$$

These findings confirm the high feasibility of the developed learning media, supporting its effectiveness in educational settings.

Implementation Result

The web-based interactive augmented reality media demonstrated an excellent level of feasibility (99%) based on Arikunto (2010) criteria, which categorizes it as "Feasible" (81%-100%). Validation by media experts yielded very positive results, although some improvements were suggested, such as enhancing the design and adding a profile page to improve comprehensiveness and usability. Field testing revealed a significant increase in student scores, with the average pre-test score rising from 72.83 to a post-test average of 87.50, an increase of 14.67 points. A total of 29 out of 30 students met the Minimum Completeness Criteria (KKM), indicating that the media effectively supported material comprehension. The Paired Samples T-Test analysis showed a significant mean difference (-14.667) with a standard deviation of 6.288, a t-value of -12.775, and a p-value of 0.000 ($p < 0.05$). According to Sadiman (2018), a significance value of 0 indicates that the difference between the data groups is highly statistically significant.

Table 2. Paired Samples Test

	Paired Differences with 95% Confidence Interval of the Difference							
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
PAIR 1 (Pre-test - Post-test)	-14.667	6.288	1.148	-17,015	-12.319	-12.775	29	.000

$$\text{Pooled SD} = \frac{(\sqrt{\text{Std } \textit{Pre-test}}\text{^2} + \sqrt{\text{Std } \textit{Post-test}}\text{^2})}{2}$$

$$\text{Pooled SD} = \frac{(\sqrt{6.254\text{^2}+5.835\text{^2}})}{2} \approx 6.5$$

Information:

Std pre : Value of std. Deviation pre-test

Std post : Value of std. Deviation post-test

$$d = \frac{(\text{Mean PostTest - Mean PreTest})}{\text{Pooled sd}}$$

$$d = \frac{(87.50 - 72.83)}{6.5}$$

$$= 2.42$$

Information:

Mean post : Average Score pre-test

Mean pre : Average Score post-test

Effectiveness measurement using Cohen's d yielded a value of 2.42, which falls into the "very large effect size" category based on Cohen's guidelines. The calculation was conducted

using a pooled standard deviation of 6.5, derived from the pre-test standard deviation (6.254) and the post-test standard deviation (5.835). A Cohen's d value of 2.42 suggests a substantial improvement in student learning outcomes, meaning that the difference between pre-test and post-test scores is not only statistically significant but also practically meaningful. In an educational context, this indicates that the use of augmented reality-based learning media leads to a significant enhancement in students' understanding and retention of the material. Such a large effect size implies that this intervention has the potential to make a meaningful difference in real classroom settings, supporting the adoption of AR technology as an effective instructional tool.

Table 3. Paired samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	*Pre-test*	72,83	30	6,254	1,142
	Post-test	87,50	30	5,835	1,065

The visualization of Cohen's d results showed that 99.2% of students' post-test scores were above the average pre-test scores, with an overlap between the two distributions of only 22.6%. The probability of a random post-test score being higher than a pre-test score was 95.6%, reinforcing the finding that the treatment had a significant impact. Additionally, the Number Needed to Treat (NNT) value of 1.3 indicates that, on average, treatment of 1.3 students is required to achieve improved learning outcomes in one student. Assuming an initial baseline where only 20% of students achieved good results prior to treatment, this proportion is estimated to increase to 94.3% after treatment. These findings affirm that the web-based interactive augmented reality learning media is highly effective in improving student learning outcomes on the topic of the human digestive system.

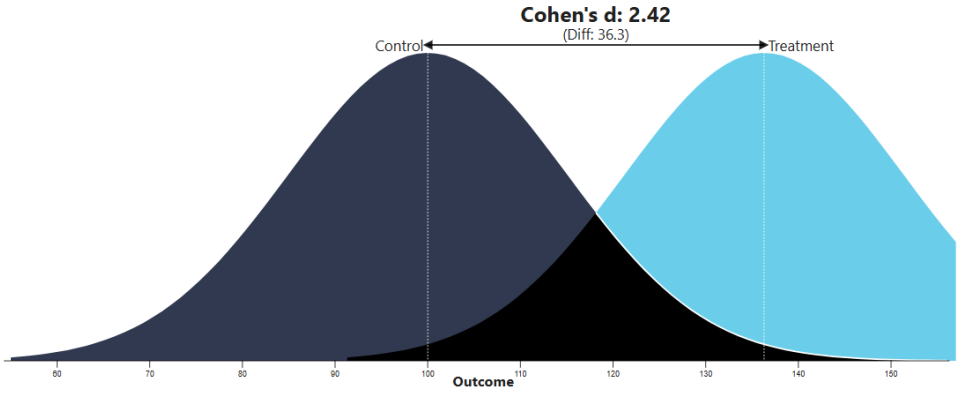

Image 2. Visualization of Cohen's d Test Results

The results of a questionnaire completed by 30 students showed highly positive responses toward the interactive infographic-based teaching materials. Three main aspects were assessed: attractiveness, ease of use, and motivation. The evaluation results indicate positive student responses regarding the attractiveness, usability, and motivational impact of the instructional media. In terms of attractiveness, this media received scores ranging from 3.13 to 3.50, with the highest rating given to its engaging and interactive material design. The

integration of text, background, and images was also well-received, providing an enjoyable learning experience. The ease of use aspect scored 3.27 to 3.40, particularly due to the media's accessibility without requiring installation, clear navigation instructions, and minimal internet data usage. Meanwhile, the motivation aspect scored between 3.20 and 3.40, as students demonstrated increased enthusiasm for learning through interactive media. With an overall average score exceeding 3.00, this media is considered highly effective, ensuring ease of use and encouraging active participation in learning.

DISCUSSION

This study found that the use of the developed media significantly enhanced learning outcomes and learning experiences. This is evidenced by a significant improvement in post-test results, with a mean difference of 10.00 ($p < 0.05$) in the small group trial (5 students) and 16.50 ($p < 0.001$) in the field trial (30 students). These findings align with previous research emphasizing the effectiveness of augmented reality as an interactive multimedia tool that enhances student learning outcomes through material visualization and exploratory engagement.

In his research, Mansur (2023) concluded that the use of augmented reality in biology education improves conceptual understanding and impacts students' cognitive, affective, and psychomotor aspects. This finding is consistent with the results of this study, which demonstrate that 3D visualization through augmented reality and an interactive website aids students in comprehending the complex structures and functions of organs more effectively. Even in other subject topics, Tika et al., (2024) and Padang et al., (2022) found that using augmented reality media via Assemblr Edu was effective in enhancing students' conceptual understanding in the excretory system and the organization of living organisms.

In addition to increasing understanding, this study also discovered that student satisfaction with learning media reached 90% based on an assessment based on visualization attractive, media design, easy to navigate, and interactivity. These results are in line with the research conducted by Zulfahmi & Wibawa (2020), which stated that Augmented Reality as an interactive digital medium could increase learning motivation and attract positive responses. Likewise, in a systematic literature review on the use of augmented reality in education, Akçayır, (2017), found out that augmented reality plays a very positive role in student motivation and interaction in learning.

The efficacy of web-based media is in line with multiple studies. As an example Anggara & Sujatmiko (2024) stated that combining web-based technology make it easier for students to access learning materials using several devices. Likewise, Sari & Ekohariadi (2024) and Anggraeni & Ekohariadi (2024) also found that the learning of web-based model significantly increases learning outcomes by experiencing interactive and project-based learning.

The outcome of enhancement in biology learning through interactive visualization is in line with Purwanti et al., (2024) who noted that visualization and interactive concepts significantly influenced the conceptual understanding of students. In addition, an extensive literature review by Garzón et al., (2019) affirmed that augmented reality led to a rise in motivation via engagement, thereby aiding learners in learning. According to their study Akçayır et al., (2016) stated that augmented reality provided introduction to science laboratories and that allowed the students to experience they use of practical skills by exploring and developed positive all around science lab projects.

Calle-Bustos et al., (2017) also believe that augmented reality is a possible learning medium in therapeutic education, which aims to assist children with diabetes in enhancing

their understanding of the diabetes condition. Moreover, Ibáñez et al,. (2018), conducting a systematic review of app-based augmented reality educational literature in STEM education, is concluded that this technology stimulates students' motivation, engagement and conceptual understanding of science, technology, engineering, and mathematics. A similar point is made by Ibáñez et al., (2016) where the role of scaffolding within augmented reality simulation systems is highlighted, which shows that providing structured guidance to students increases their learning outcomes and engagement significantly.

The learning outcomes of conceptual material from this study was in line with the findings of Chen et al., (2016), who reported the development of an AR-based concept map for science learning through mobile devices, which was works well in improving the students concept understanding. Likewise, Amrina et al., (2023) revealed that Augmented Reality application in Mathematics education helps students understand three-dimensional geometry concepts better.

Designed media designs (helps students learn by observing content and exploring the material)1 with the results of research conducted by Zuana et al., (2023), namely: AR applications in SKI subjects significantly develop students' learning outcomes through exploratory activities. Similarly, in the research conducted by Wardani & Turahmat (2024) regarding students' perceptions of AR in Indonesian language learning, they found that in general, most students viewed AR as a highly beneficial media for improving their learning achievement. This study's development results and previous research findings provide evidence to support the opinion that the application of augmented reality (AR) media is beneficial to assist students in learning complex subjects observations and exploration in each organ of the human digestive system. By integrating visualizations with an interactive media design, students become more engaged in the learning process and take on a more participatory perspective. Also, web-based approach of AR has been utilized to overcome the drawbacks of previous studies where AR was implemented as mobile application. Web-based option is more accessible and works across multiple devices, but it needs a stable internet connection. Additionally, the differences in subject matter in previous studies highlight the potential for AR development beyond just science or biology topics, opening opportunities for broader applications.

CONCLUSION

The researcher successfully developed an interactive web-based Augmented Reality learning media that is both effective and efficient for teaching the human digestive system to Grade XI students. This media has been validated by subject matter and media experts. The conclusion is also supported by the results of its implementation at SMAN Rambipuji. The study findings indicate that the application of the developed media significantly improved post-test scores compared to pre-test scores, with a notable increase (mean difference of 10.00; $p < 0.05$ for the small group test and mean difference of 16.50; $p < 0.001$ for the large group test). From the perspective of students' user experience—measured in terms of media attractiveness, interactivity, ease of use, and content visualization—questionnaire results show a very high satisfaction rate, reaching up to 90%. Expert validation results confirm its feasibility, with 96% approval in the material aspect and 99% in the media aspect, affirming its relevance, engagement, and ease of use. These findings align with the research objective of developing an innovative digital learning tool that enhances students' learning experience. Future research could focus on expanding AR-based learning media to other biological topics, integrating adaptive learning features, and exploring its long-term impact on students'

academic performance. Furthermore, this study contributes to the evolution of digital learning technologies by demonstrating how AR and web-based platforms can revolutionize science education, making abstract biological concepts more tangible, engaging, and interactive.

REFERENCES

Abdullah, A., & Rery, R. U. (2022). Feasibility analysis of four tier multiple choice diagnostic test instruments on reaction rate material. *Jurnal Pendidikan Sains Universitas Muhammadiyah*, *10*(2), 44-52. https://doi.org/10.26714/jps.10.2.2022.44-52

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with Augmented Reality for education: A systematic review of the literature. *Educational research review,* 20, 1-11. https://doi.org/10.1016/j.edurev.2016.11.002

Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior*, *57*, 334–342. https://doi.org/10.1016/j.chb.2015.12.054

Alqurashi, E. (2019). The impact of interactive learning on students' understanding of complex scientific concepts. *International Journal of STEM Education*, *6*(1), 1–15. https://doi.org/10.1186/s40594-019-0172-3

Amrina, Z., Sari, S. G., Alfino, J., & Mahdiansyah, M. (2023). Pengembangan Media Pembelajaran Matematika Berbasis Augmented Reality untuk Meningkatkan Kompetensi Mahasiswa. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *7*(1), 380–391. https://doi.org/10.31004/cendekia.v7i1.1932

Anggara, A. D., & Sujatmiko, B. (2024). Implementasi Media Pembelajaran Berbasis Website Dalam Kompetensi Desain Produk Multimedia Untuk Meningkatkan Hasil Belajar Siswa Pada Mata Pelajaran Desain Media Interaktif Bagi Siswa Smk. *IT-Edu : Jurnal Information Technology and Education*, *9*(1), 63–72. https://doi.org/10.26740/it-edu.v9i1.58645

Anggraeni, N. D. R., & Ekohariadi, E. (2024). Pengembangan Media Pembelajaran Berbasis Website Dengan Model Pembelajaran Problem Based Learning Pada Mata Pelajaran Cloud Computing Di Smkn 1 Kemlagi. *IT-Edu : Jurnal Information Technology and Education*, *9*(1), 26–31. https://doi.org/10.26740/it-edu.v9i1.58276

Arikunto, S. (2010). *Prosedur Penelitian: Suatu Pendekatan Praktik*. Rineka Cipta.

Cahyaningrum, R., Junaedi, I., & Ichwan, H. (2022). Implementasi Augmented Reality Pada Media Pembelajaran Animasi 3D Sistem Pencernaan Manusia Berbasis Android. *Jurnal Manajamen Informatika Jayakarta*, *2*(4), 337. https://doi.org/10.52362/jmijayakarta.v2i4.918

Calle-Bustos, A. M., Juan, M. C., García-García, I., & Abad, F. (2017). An augmented reality game to support therapeutic education for children with diabetes. *PLoS ONE*, *12*(9), 1–23. https://doi.org/10.1371/journal.pone.0184645

Carolina, Y. D. (2023). Augmented reality sebagai media pembelajaran interaktif 3D untuk meningkatkan motivasi belajar siswa digital native. *Ideguru: Jurnal Karya Ilmiah Guru*, *8*(1), 10-16. https://doi.org/10.51169/ideguru.v8i1.448

Chen, C. H., Chou, Y. Y., & Huang, C. Y. (2016). An Augmented-Reality-Based Concept Map to Support Mobile Learning for Science. *Asia-Pacific Education Researcher*, *25*(4), 567–578. https://doi.org/10.1007/s40299-016-0284-3

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences (2nd ed.)* (2nd ed.). Routledge.

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented

reality in educational settings. *Virtual Real.*, *23*(4), 447–459. https://doi.org/10.1007/s10055-019-00379-9

Gunawan, T. (2023). Penerapan Teknologi Augmented Reality Untuk Pengalaman Pengguna Dalam Aplikasi Edukasi. *Jurnal Review Pendidikan Dan Pengajaran*, *6*(4), 4362–4368. https://doi.org/10.31004/jrpp.v7i2.28013

Hasan, A., & Widodo, D. (2018). Human digestive system: Structure and function. *Journal of Biological Education*, *13*(1), 45–57. https://doi.org/10.12345/jbe.2018.12345

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, *123*, 109-123. https://doi.org/10.1016/j.compedu.2018.05.002

Ibáñez, M. B., Di-Serio, Á., Villarán-Molina, D., & Delgado-Kloos, C. (2016). Support for Augmented Reality Simulation Systems: The Effects of Scaffolding on Learning Outcomes and Behavior Patterns. *IEEE Transactions on Learning Technologies*, *9*(1), 46–56. https://doi.org/10.1109/TLT.2015.2445761

Ioannou, A., Vasiliou, C., Zaphiris, P., Arh, T., Klobučar, T., & Pipan, M. (2015). Creative Multimodal Learning Environments and Blended Interaction for Problem-Based Activity in HCI Education. *TechTrends*, *59*(2), 47–56. https://doi.org/10.1007/s11528-015-0839-9

Mansur S. (2023). Penggunaan Media Augmented Reality (Ar) terhadap Hasil Belajar Biologi Siswa. *Journal on Teacher Education*, *5*(2), 160–166. https://doi.org/10.31004/jote.v5i2.20622

Padang, F. A. L, Ramlawati, R., & Yunus, S. R. (2022). Media Assemblr Edu Berbasis Augmented Reality Untuk Meningkatkan Hasil Belajar Materi Sistem Organisasi Kehidupan Makhluk Hidup. *Diklabio: Jurnal Pendidikan Dan Pembelajaran Biologi*, *6*(1), 38–46. https://doi.org/10.33369/diklabio.6.1.38-46

Purwanti, P., Diana, R., Mulyadin, M., Yusup, F., & Fauzi, R. N. (2024). Penggunaan Media Augmented Reality dalam Pembelajaran IPA untuk Meningkatkan Pemahaman Konsep. *Jurnal Informatika dan Teknologi Pendidikan*, *4*(2), 67-73. https://doi.org/10.59395/jitp.v4i2.98

Putra, Gusti, Made. Santosa, Made. Arya. Suarni, Ni, K. (2021). The effect of Augmented Reality on students' academic achievement and engagement in biology classes. *Cogent Education*, *8*(1). https://doi.org/10.1080/2331186X.2021.1881548

Riyanto, D., & Jollyta, D. (2023). Penerapan Augmented Reality Pengenalan Sistem Pencernaan Manusia Dengan Metode Marker Based Tracking Sebagai Media Pembelajaran. Jurnal Mahasiswa Aplikasi Teknologi Komputer Dan Informasi, 5(1), 42–47.

Sadiman, A. (2018). *Media pendidikan: Pengertian, pengembangan, dan pemanfaatannya*. Raja Grafindo Persada.

Sari, A. W. M., & Ekohariadi, E. (2024). Pengembangan Media Pembelajaran Berbasis Website Pada Mata Pelajaran Informatika Dengan Model Pembelajaran Project Based Learning Kelas X Tkj Smkn 7 Surabaya. *IT-Edu : Jurnal Information Technology and Education*, *9*(1), 17–25. https://doi.org/10.26740/it-edu.v9i1.58275

Supriyadi, M. N., Ramdhan, B., & Juhanda, A. (2022). Efektivitas Media Augmented Reality Berbasis Smartphone Terhadap Kemampuan Komunikasi Visual dan Motivasi Siswa Pada Pembelajaran Biologi. *BIODIK*, *8*(3), 99-109. https://doi.org/10.22437/bio.v8i3.18857

Tika, P. N., Nisa, S. F., Faturahmah, D., Ristanto, R. H., & Isfaeni, H. (2024). Pengembangan Augmented Reality Berbantuan Assemblr Edu untuk Meningkatkan Pemahaman Konsep Sistem Ekskesi. *Diklabio: Jurnal Pendidikan dan Pembelajaran Biologi*, *8*(1), 52-64. https://doi.org/10.33369/diklabio.8.1.52-64

Susilawati, K. (2018). *Buku ajar anatomi fisiologi dan gangguan sistem pencernaan*. Trans Info Media.

Utami, A. U., & Murti, S. C. C. (2018). The Effectiveness of Scientific Approach-Based Science Learning Materials to Educate Students Science. *Jurnal Penelitian Pendidikan Sains*, *8*(1), 1553–1557. https://doi.org/10.26740/jpps.v8n1.p%25p

Wardani, O. P., & Turahmat, T. (2024). Persepsi Mahasiswa terhadap Penggunaan Augmented Reality (Ar) sebagai Media Ajar Bahasa Indonesia. *Sasindo*, *12*(1), 146–150. https://doi.org/10.26877/sasindo.v12i1.18383

Zuana, T. Y., & Aziz, H. (2023). Pengaruh media augmented reality terhadap hasil belajar sejarah kebudayaan Islam. *Jurnal Riset Pendidikan Agama Islam*, 147-152. https://doi.org/10.29313/jrpai.v3i2.3059

Zulfahmi, M., & Wibawa, S. C. (2020). Potensi Pemanfaatan Augmented Reality Sebagai Media Pembelajaran Terhadap Motivasi Belajar dan Respon Siswa. *Jurnal IT-EDU*, *5*(1), 334–343. https://doi.org/10.26740/it-edu.v5i1.37491