Journal of Research in Instructional
e-ISSN: 2776-222X
Vol. 4(2) 2024, pp. 453 – 464
https://doi.org/10.30862/jri.v4i2.459

Development of augmented reality human skeleton to improve students' cognitive learning outcomes on movement systems practice

Mochammad Hilman Amirudin Nahri*, Zainul Abidin, Yerry Soepriyanto

Universitas Negeri Malang, Indonesia

Submitted: 13-08-2024

Accepted: 22-09-2024

Published: 24-09-2024

Abstract: The purpose of this study was to develop and reveal the effect of using Augmented Reality Human Skeleton in learning of human movement system on students' cognitive learning outcomes. This study uses the Multimedia-Based Instructional Design development model from Lee & Owens. The developed media was tested for validity. Cognitive ability was measured using a description test and a paired t test was carried out. Researchers validated the product through material experts and obtained a perfect score, with a score of 100% for content quality and objectives and learning quality, which was stated as Very valid. Media validation also showed very good results, with a score of 100% for suitability, attractiveness, and usefulness, and 95% for Simplicity. In addition, the practicality test of the media by students obtained a score of 96% for appearance, 97% for convenience, and 95% for ease of understanding the material, all of which were stated as practical. The results of the study showed a significant influence of the implementation of this media on students' cognitive learning outcomes. The use of Augmented Reality Human Skeleton showed a significant increase in students' cognitive (pretest = 61.1 and posttest 87.9). Thus, the application of Augmented Reality Human Skeleton in learning the human movement system is proven valid, practical, and able to improve students' cognitive learning outcomes.

Keywords: Augmented reality, cognitive outcomes, movement system

Abstrak: Tujuan penelitian ini adalah untuk mengembangkan dan mengungkap pengaruh penggunaan Augmented Reality Human Skeleton dalam pembelajaran sistem gerak manusia terhadap hasil belajar kognitif siswa. Penelitian ini menggunakan model pengembangan Multimedia-Based Instructional Design dari Lee & Owens. Media yang dikembangkan diuji validitasnya. Kemampuan kognitif diukur dengan tes uraian dan dilakukan uji t berpasangan. Peneliti melaksanakan validasi kepada produk melalui ahli materi dan memperoleh nilai sempurna, dengan skor 100% untuk kualitas isi dan tujuan serta kualitas pembelajaran, yang dinyatakan Sangat valid. Validasi media juga menunjukkan hasil yang sangat baik, dengan skor 100% untuk kesesuaian, kemenarikan, dan kemanfaatan, serta 95% untuk kemudahan penggunaan. Selain itu, uji kepraktisan media oleh siswa diperoleh skor 96% untuk tampilan, 97% untuk kemudahan penggunaan, dan 95% untuk kemudahan pemahaman materi, yang semuanya dinyatakan praktis. Hasil penelitian menunjukkan adanya pengaruh signifikan dari implementasi media ini terhadap hasil belajar kognitif siswa. Penggunaan Augmented Reality Human Skeleton menunjukkan adanya peningkatan signifikan pada kognitif siswa (pretest = 61.1 dan posttest 87.9). Dengan demikian, penerapan Augmented Reality Human Skeleton dalam pembelajaran sistem gerak manusia terbukti valid, praktis dan mampu meningkatkan hasil belajar kognitif siswa.

Kata kunci: Augmented reality, hasil belajar kognitif, sistem gerak

*Corresponding author: hilman.amirudin@teknologipendidikan.or.id

INTRODUCTION

Interactive teaching strategies and student engagement are essential to prepare students to face global challenges (Chastnyk et al., 2024). Education is experiencing a dynamic and significant development, focusing not only on student understanding but also on competence and technology users (Ihsan et al., 2024; Karina et al., 2024; Nwafor et al., 2022). This development is in line with the implementation of an independent curriculum

that focuses on intra-curricular learning and optimizes content in understanding concepts, strengthening competence, character development, and giving flexibility (Hanipah, 2023). The application of this curriculum aims to prepare students in the face of a changing world and improve the quality of life through technological advances (Sa'diyah et al., 2023).

Biology becomes one of the lessons that relate to the facts, concepts, principles, and processes of the symptoms of life. Biological matter is seen as a complex and complex matter, one of which is the material of the human movement system that exists in class XI (Fadillah et al., 2022). Based on the decision of the head of the curriculum and assessment standards of education, access to biology learning class XI relates to the ability to describe, analyze, apply, and evaluate the correlation of organ structures in organ systems such as the movement system in solving problems of everyday life. According to Anggarani et al. (2024) movement system content was considered difficult for students cause many scientific terms are associated with the names of joints, bones, muscles, and disorders on this material.

Scientific and technological developments have a positive impact by expanding global access to information, but also bring challenges in its implementation, especially in the field of education (Putri & Syafitri, 2023). One way to improve students' learning understanding and motivation is by using learning media (Aditia, 2024). Learning media is a tool or material to convey information, concepts, or learning material to students (Dita et al., 2024). Interactive media is one of the learning media that can increase motivation, learning spirit, stimulate the learning process, as well as provide psychological impact for students (Setyantoko et al., 2023; Tang & Hew, 2022). The presence of interactive media in learning is essential to create learning that is centered on student activity. The more students engage with the material during the learning activities, the more their knowledge, attitudes, and skills develop (Effendi et al., 2023). The rapid development of technology and the increasing need for immersive interactive media are increasingly urgent in the development of education.

Applications of technology in learning, such as integration of learning resources, student worksheets, and learning media, are in great need (Putri & Syafitri, 2023). Supported by observations at MAS Tarbiyyatus Shibyan Tajinan, teachers use technology in the preparation of teaching modules, handouts, and teaching resources through power points (PPT). The results of an interview with one of the biology teachers of MAS Tarbiyyatus Shibyan Tajinan and a student of the XI class of mathematics and science stated that biology is a difficult subject and less sought by students especially the matter of the human movement system because of the material quite difficult, wide coverage, and many problems studied in the material of human movement systems. This problem affects the low cognitive learning outcomes of students, as much as 45% of XI class students of MAS Tarbiyyatus Shibyan Tajinan score below the Minimum Completeness Criterion of 75. Low cognitive learning outcomes in students of biology can occur because the extent of the material coverage makes it difficult for students to understand the material in it (Zebua, 2023).

The lack of use of technology in biology learning, especially the material of the movement system, worsened students' cognitive learning outcomes. Based on the results of the filling of the lift by 28 students of MAS Tarbiyyatus Shibyan Tajinan against the learning media, teachers using modules, PPT, and LKS were deemed less attractive to read. Torso of the movement system is broken and incomplete. The video media used by the teacher as a

PPT video recording is considered boring by the students. Students have difficulty mastering the ability to analyze the movement system and function of organs in the human body. The lift filling results also showed that 76.8% of students needed and liked the projected image media to understand the material of the movement system. Therefore, supportive media, such as Augmented Reality (AR), are needed to package the material more effectively and improve student thinking and understanding (Damopolii et al., 2022; Fitria, 2023).

Augmented Reality (AR) is a technology that incorporates 2D or 3D virtual objects in a real environment and projects them in real time through markers captured by the camera. AR aims to unite the real world with virtual technology and add contextual data to clarify user understanding (Pringgar & Sujatmiko, 2020). AR applications can be done in a variety of ways and media, including the use of markers, sensors, applications, even through social media such as Instagram (Azuma et al., 2001).The application of AR in learning is not apart from teaching methods, it is necessary to have the appropriate module breastfeeding so that students have easy access to teaching media (Aditia, 2024). Teacher-centered becomes one of the chosen approaches to implementing this media. The interaction of students and teachers in the same direction will increase the focus of students to be longer, memorable, and easy to understand (Astini, 2023).

Based on the explanation, 3D technology such as AIR can help students learn to understand anatomical structures, and ultimately make their concepts stronger. It is expected that the development of this media can be a solution for improving the cognitive learning outcomes of students, as well as developing digital literacy in students. The aim of this research is to develop and reveal the influence of the use of Augmented Reality Human Skeleton in the learning of human movement systems on the cognitive learning outcomes of students

METHOD

This research and development applies the multimedia-base instructional design model of Lee and Owens (2004). This model was chosen because it focused on the use of interactive multimedia technology and development. Lee and Owens (2004) It's a procedural phase that's structured, concise, and clear. The five stages of the model include analysis consisting of need assessment and front-end analysis, design, development and implementation, and evaluation. The Lee and Owens model diagrams are described in detail in Figure 1.

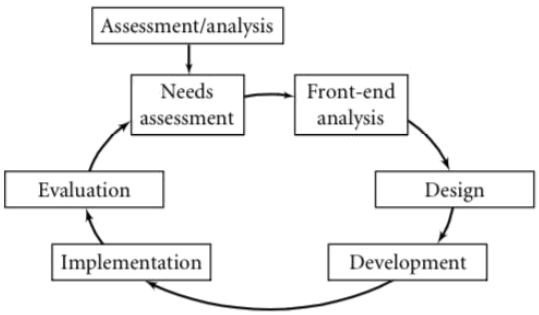

Fig 1. Lee and Owens' model chart (Source: Lee & Owens, 2004)

The test subjects involved a Biology teacher, ten students for a practicality test, and 18 students of the 11th grade of the science major as a subject of implementation. The research was carried out at MAS Tarbiyyatus Shibyan Tajinan, in July 2024. The data collected includes quantitative and qualitative data. Quantitative data comes from analysis of student responses and validity score results involving material validators, media, and field practitioners. Meanwhile, qualitative data is obtained from the description of comments and advice taken from student questionnaires, biological education practitioners (teachers), material expert validation sheets, and media expert validations sheets.

The tools used to evaluate the validity of mobile learning media include the validation sheet instrument, the practicality test sheets instrument, and the student response questionnaire sheet instruments. Validation aims to explain the media validity level so that it can be implemented (Sugiyono, 2019). The validity assessment of 3D media modeling is carried out by media experts and material experts using a validation sheet that includes indicators such as user interface aspects, usability, ease of use, content validity, usabilidad, and presentation validity. The practicality of the teacher is assessed by the practitioner (teacher) through a practicality lift with indicators of material clarity, media ease, and the suitability of the device to learning. The student's response is evaluated through a student response lift that evaluates the ease of use of the media, the clarity of the material, and device compatibility with learning. The multiple choice has been adjusted to the Bloom taxonomy level to see the effectiveness of media in influencing cognitive learning outcomes (Magdalena et al., 2021).

Validation tests in augmented reality human skeleton educational games include validation of material, media, learning devices, practitioners, and issues. The criteria used are described as follows. Validation data by media experts, materials, learning devices, and practitioners consists of qualitative data in the form of criticism and advice, as well as quantitative data measured using the Likert scale. The data obtained will then be analyzed using the prescribed formulas and terms.

$$P = \frac{\sum X}{\sum Xi} \text{ x } 100\% \quad (1)$$

Description:
P : Presentation
$\sum X$: Total Score
$\sum X_i$: Maximum Score

The percentage calculated using the provided formula was employed to assess the validity of the media. Validity was determined based on Akbar (2013), the percentage calculated using the provided formula was employed to assess the validity of the media. Validity was determined based on Dita et al. (2023), and Damopolii et al. (2022) in the development of instructional media. The data analysis technique for practicality was conducted by students as users. The level of practicality of the instructional media was interpreted into quantitative data using the criteria (Akbar, 2013; Damopolii et al., 2022; Dita et al., 2023). The entire assessment is evaluated by two lecturers who have expertise in their field. The questionnaires are measured using a percentage formula and evaluated on the Likert scale. Open questions are structured in such a way that they can be easily answered once the respondent understands them.

The data obtained in this study was analyzed using descriptive and inferential statistical analysis. Descriptive statistical analyses were performed to describe cognitive learning outcomes. Inferential analysis used pairs of T-tests to determine the significance of differences in cognitive learning outcome rates between pretest and posttest. The data analysis is done with the SPSS program, starting with the pre-conditional normality. The normality tests are performed using the Shapiro-Wilk test.

RESULTS AND DISCUSSION

Analysis

The stage of analysis is divided into need analysis and front-end analysis. In the stage of need analysis, the first step is to determine the current state of affairs by finding the root of the problem (Lee & Owens, 2004). Interviews with Biology Teacher revealed that students had difficulty understanding the practical material of the movement system due to the limitations of incomplete and only interchangeable torso instruments in schools, as well as lack of knowledge about the latest applications for modern teaching. Interview with students showed that they had difficulties in the practice of movement systems because of the torso tools that had to be used interchangeably in limited time, the tendency of students not to ask when they did not understand, and the view that conventional learning was boring.

Step define the job is done by giving a questionnaire to students to know their level of interest and opinions about interactive games (Firdaus et al., 2024). The set priorities for action phase is done by collecting data from student questionnaires. 73% of students are already accustomed to using technology, especially smartphones with use of up to 75%. Students' interest in smartphone-based learning media is at 83%, so it can be concluded that technology-based media is more readily accepted by students.

At the front-end analysis stage, an audience analysis was conducted involving students in the eleventh grade of mathematics and science with the age range of 16-17 years who have a background in the use of technology. In technology analysis, MAS Tarbiyyatus Shibyan Tajinan has a good computer lab, and every student already has adequate equipment. In task analysis, it is expected that researchers will be able to produce valid and practical technology-based media (Lee & Owens, 2004). Media analysis shows that the selected media is an interactive game in the form of an application.

Design

The design stage produces a course design specification (CDR) that includes schedules, project teams, media specifications, learning structures, and control configurations. Schedules are made to determine the duration of media production and are adapted to the timetable for the implementation of the student's coordination system material. The project team consists of researchers as conceptors and designers, programmers, human physiological anatomical material experts, learning media experts, and learning device experts. Media specifications include display aspects, audio, video, user interface design, text design, theme selection, font size, and output file types of the media developed to fit the target user and be easy to understand.

This developmental research produces media in the form of augmented reality 3D as an Instagram filter. The learning structure in this media begins with the determination of

the content and structure of learning based on access learning (CP) which studies the relationship between the structure of the organ-building tissue in the movement system in relation to the bioprocesses and the disruption of functions that can occur in the human movement system (Sari, 2023). The media control and layout configuration explains how to control the media as well as the design of each element used in the media.

Development process

The development stages are divided into preproduction, production, postproduction, and quality review, as illustrated in Figure 2. Preproduction begins with identifying problems that continue with the development of media based on the material of the movement system and detecting damage to the torso media that became the primary learning medium of the material of the movement system, which has an impact on the learning activities of teaching. Lack of adequate media reduces student enthusiasm, learning motivation, and cognitive learning outcomes on complex materials (Pratama, 2022).

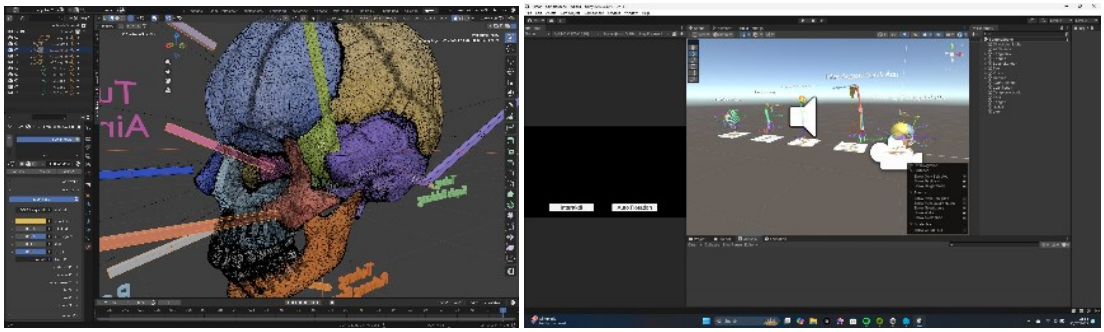

Fig. 2. Human skeleton AR development stage

The production phase is carried out with the development of 3D objects of the human body frame using the Blender application that refers to the teaching materials and storyboards that have been created. The developing skeletal objects include the skull, the spine, the chest, and the rhinoceros, the upper movable bones (hands), and the lower movable bone (foot). After that, 3D model perfection is carried out at the next stage by integrating it into the AR environment.

Postproduction becomes the third phase involving optimization of 3D models, integration into AR environments, interaction development, as well as testing and adaptation. 3D model optimization begins with model cleaning to remove noise, seam, or unwanted artifacts on 3D models. Next, textured by giving texture to the bone to give a more realistic look and the last is rigging by adding bone and control to the model to allow for more flexible animation. If the 3D media is considered suitable, it will be integrated into the AR environment by choosing the AR Engine (Unity) to design an AR environment, from the human frame layout to the appropriate lighting selection. A suitable AR environment will develop its interaction by defining user input, responsive animation, and clear visual feedback. To ensure that the AR developed is usable, device testing is carried out to test compatibility, performance testing to ensure application performance smoothness, and adjustment of models, animations, and environments based on the tests carried (Pratama, 2022).

The last stage of development is a quality review to ensure the quality standard of the Human Skeleton AR. Several aspects are noted including anatomical accuracy, visual quality, performance, interactivity, and user experience. If it is felt that the

Implementation process

Human Skeleton AR has met the standard, it will be implemented in 10 students of XI grade of mathematics and science MAS Tarbiyyatus Shibyan Tajinan who are studied in Figure 3.

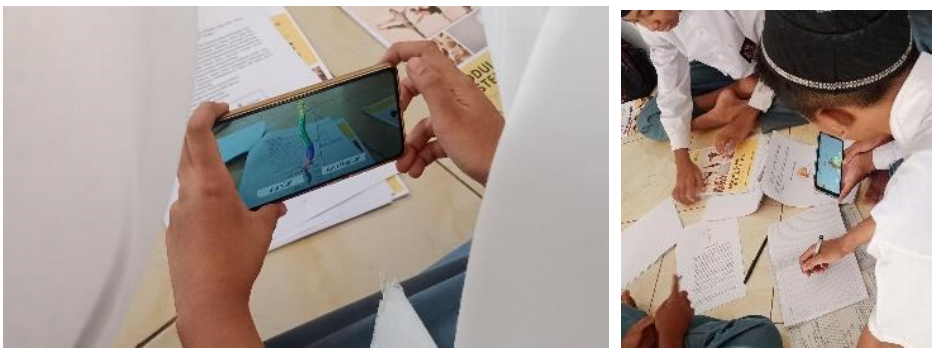

Fig. 3. Human skeleton AR implementation

Figure 3 explains the implementation of the Human Skeleton AR that motivates students to learn the material of the movement system that has an impact on improved student understanding. Augmented Reality (AR) enables more concrete and interactive visualization of abstract concepts. Students can interact directly with complex 3D models, enhancing their skills to analyze, evaluate, and synthesize information in greater depth (Aditia, 2024). Not only that, Human Skeleton AR also facilitates experiential learning, which encourages students to think critically and creatively in solving problems, enhance their involvement, and strengthen cognitive understanding at a higher level. Thus, the use of Human Skeleton AR feels more practical, effective, and capable of enhancing students' cognitive understanding of the material of the movement system.

Evaluation

The evaluation stage in this research consists of four levels, namely reaction, knowledge, performance, and impact. The evaluation starts by conducting face validity by media experts to ensure that the materials used are in accordance with the expected standards. Next, content validity was conducted by material experts, practitioner validators, and learning device validators to evaluate the suitability of the content with the learning objectives.

Table 3. Material validation results

No	Assessed aspects	Percentage (%)	Description
1	Quality of content and objectives	100	Very valid
2	Quality of learning	100	Very valid

The results of the evaluation of the materials are shown in Table 3, where the expert gave a perfect score of 100% on both the quality of content and purpose and the quality of learning. Both aspects were declared "highly valid", indicating that the material not only

met high quality standards, but also supported the learning process effectively. In addition to the materials, the media used in this study were also validated through four main aspects, namely suitability, attractiveness, convenience, and usefulness, as shown in Table 4.

Table 4. Media validation results

No	Assessed aspects	Percentage (%)	Description
1	Suitability	100	Very valid
2	Attractiveness	100	Very valid
3	Simplicity	95	Very valid
4	Usefulness	100	Very valid

Table 4. The media received excellent ratings with a score of 100% for suitability, attractiveness and usefulness, and 95% for ease of use. All aspects were declared "Highly valid", indicating that the media is suitable for learning purposes, attractive to users, easy to use, and provides significant benefits.

Table 5. Practicality data results

No	Assessed aspetcs	Percentage (%)	Description
1	Appearance	96	Very practice
2	Convenience	97	Very practice
3	Ease of understanding the material	95	Very practice

Furthermore, a practical test of the media was conducted involving 10 students of MAS Tarbiyyatus Shibyan Tajinan before implementation. Students were directed to utilise the media and fill in the practicality questionnaire. The results of the practicality test, summarised in Table 5, show that the display aspect of the media obtained an average of 96%, ease of use 97%, and ease of understanding the material 95%, all with the category "Very practice". The use of Augmented Reality (AR) on Human Skeleton integrated with Instagram filters is proven to increase convenience for students because they do not need to install additional AR applications. Simply by opening Instagram and using the camera feature, technical barriers and device limitations can be minimized, making this media more friendly to various types of devices.

Table 6. Results of pretest and posttest normality test

Data	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest	0.916	18	0.109
Posttest	0.915	18	0.104

The evaluation continued to level 2, where the effectiveness of the media on improving students' cognitive outcomes was tested on 18 students using a paired t-test to see the significance. Prior to this, a normality test was conducted, as presented in Table 6. In accordance with Table 6. It is possible to infer that all data are normally distributed. as the Shapiro-Wilk normality test yielded a significance value greater than 0.05.

Table 7. Paired T test results

	Mean	t	df	Sig.
Pair - Pretest & Posttest	-12.00000	-6.705	17	0.000

The t-test results, presented in Table 7, showed a significant correlation, with pretest and posttest scores increasing significantly, with a mean pretest score of 61.1 and posttest score of 87.9 as shown in Figure 4.

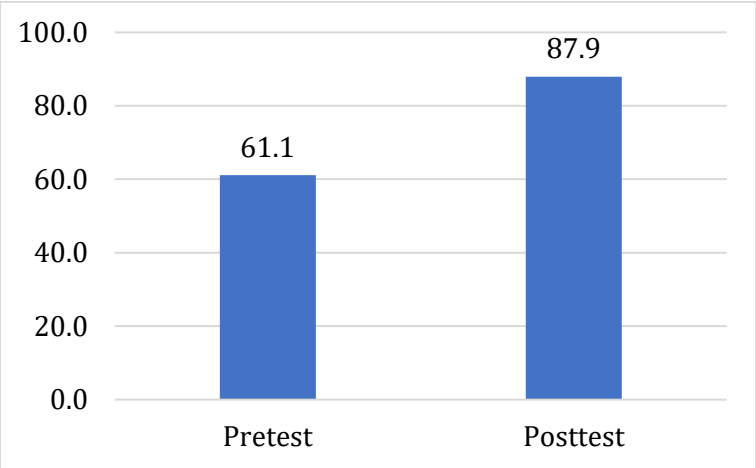

Figure 4. Pretest and Posttest Graphs

Cognitive improvement at the cognitive output level represented for the pretest and posttest, can occur because the Human Skeleton AR provides meaningful learning for students. In the pretest students only gave basic answers relating to the skills of remembering, understanding, and applying information. In contrast, in the posttest taken after the implementation of the Human Framework AR, students provided answers with more complex critical thinking skills, including analyzing, evaluating, and creating new solutions or ideas (Falentina et al., 2021).

The implementation of AR Human Skeleton can be seen in students' posttest answers which are more detailed than the pretest. The use of AR Human Skeleton allows students to remember and understand the concept of the movement system with clear and concrete visualizations, such as 3D models of bones that can improve cognitive outcomes (Effendi et al., 2023). AR media also provides experience to analyze and evaluate how the coordination of bones and muscles in a movement. This media facilitates students to create innovations through the integration of information obtained through AR into everyday problems that students are familiar with. Not only that, AR Human Skeleton is able to increase motivation and an exciting learning experience for students. So that this media not only strengthens conceptual understanding but also encourages critical and creative thinking.

Based on the investigations carried out, there is a need for wider implementation in some classes and some schools. It is necessary to generalize wider and comprehensive research on the effectiveness of the learning media material of the movement system. The development of media on other materials is also necessary to address the low learning motivation in students.

CONCLUSION

The development and implementation of the Human Skeleton AR showed significant results on students' cognitive learning outcomes. These media enable students to visualize the movement system in depth through 3D models thus strengthening their understanding and application of abstract concepts. The results indicate that the use of AR can be an effective tool for improving cognitive learning outcomes on movement system material, although further evaluation is needed to ensure generalization of the findings into a broader context.

REFERENCES

Aditia, R. (2024). Peran dan Tantangan Teknologi Augmented Reality dalam Meningkatkan Pengalaman Pengguna Media. *Jurnal Ilmu Sosial Dan Humaniora*, *4*(1), 35–43. https://ejournal.amertamedia.co.id/index.php/amerta/article/view/197

Akbar, S. (2013). *Instrumen perangkat pembelajaran*. PT Remaja Rosdakarya.

Anggarani, D. A., Sari, M. S., & Fitriyati, U. (2024). Development of e-comic based on problem-based learning human movement system material to train problem-solving skills and students' cognitive learning outcomes in SMA Islam Almaarif Singosari. *AIP Conference Proceedings*, *3106*, 030008. https://doi.org/10.1063/5.0215924

Astini, G. N. (2023). Model Group Investigation untuk Meningkatkan Hasil Belajar Biologi Siswa Kelas X IPA 1 SMA. *Journal of Education Action Research*, *7*(2), 298–302. https://doi.org/10.23887/jear.v7i2.60216

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, *21*(6), 34–47. https://doi.org/10.1109/38.963459

Chastnyk, O., Zoria, M., Poletay, O., Shumskyi, O., & Klochkova, Y. (2024). Exploring the influence of interactive education on academic progress: Evaluating effectiveness and implementation approaches. *Multidisciplinary Reviews*, *7*, 2024spe029. https://doi.org/10.31893/multirev.2024spe029

Damopolii, I., Nunaki, J. H., Jeni, J., Rampheri, M. B., & Ambusaidi, K. A. (2024). An Integration of Local Wisdom into a Problem-based Student Book to Empower Students' Conservation Attitudes. *Participatory Educational Research*, *11*(1), 158–177. https://doi.org/10.17275/per.24.10.11.1

Damopolii, I., Paiki, F. F., & Nunaki, J. H. (2022). Comic assisted by augmented reality: Its use to empower students' critical thinking skill. *AIP Conference Proceedings*, *2542*, 030003. https://doi.org/10.1063/5.0104082

Dita, K. I., Nunaki, J. H., Nasir, N. I. R. F., Winarno, N., Damopolii, I., & Latjompoh, M. (2024). Flipbook digital sistem peredaran darah manusia: Dampaknya terhadap hasil belajar siswa. *Biogenesis*, *20*(2), 55–70. http://dx.doi.org/10.31258/biogenesis.20.2.55-70

Dita, K. I., Tuririday, H. T., Damopolii, I., & Latjompoh, M. (2023). Designing the human circulatory system e-module to increase student achievement. *Inornatus: Biology Education Journal*, *3*(2), 75–84. https://doi.org/10.30862/inornatus.v3i2.422

Effendi, Q. N. A., Listiawati, M., & Yusup, I. R. (2023). Keterampilan Berpikir Sistem Menggunakan Model Discovery Learning Pada Materi Sistem Gerak Manusia. *Bioedutech: Jurnal Biologi, Pendidikan Biologi, Dan Teknologi Kesehatan*, *2*(2), 11–20.

https://jurnal.anfa.co.id/index.php/biologi/article/view/1363

Fadillah, H. N, Ismail, I., & Mu'nisa, A. (2022). Pengaruh Model Pembelajaran Inkuiri Terhadap Kemampuan Berpikir Tingkat Tinggi Siswa Pada Materi Sistem Gerak Kelas Xi Sma Negeri 3 Wajo. *Jurnal Biogenerasi*, *7*(1), 197–205. https://doi.org/10.30605/biogenerasi.v7i1.1722

Falentina, A. R., Saptasari, M., & Indriwati, S. E. (2021). Keterampilan Berpikir Kritis melalui Penerapan Model Pembelajaran Inkuiri Terbimbing di Kelas XI IPA. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *5*(10), 1397–1404. https://doi.org/10.17977/jptpp.v5i10.14100

Firdaus, Z., Zubaidah, S., & Munzil. (2024). Pengembangan edugame pada materi sistem saraf untuk siswa SMA. *Bioscientist : Jurnal Ilmiah Biologi*, *12*(1), 1472–1488. https://doi.org/10.33394/bioscientist.v12i1.11924

Fitria, T. N. (2023). Augmented Reality (AR) and Virtual Reality (VR) technology in education: Media of teaching and learning: A review. *International Journal of Computer and Information System (IJCIS)*, *4*(1), 14–25. https://doi.org/10.29040/ijcis.v4i1.102

Hanipah, S. (2023). Analisis Kurikulum Merdeka Belajar Dalam Memfasilitasi Pembelajaran Abad Ke-21 Pada Siswa Menengah Atas. *Jurnal Bintang Pendidikan Indonesia (JUBPI)*, *1*(2), 264–275. https://doi.org/10.55606/jubpi.v1i2.1860

Ihsan, M. S., Husain, P., Fauziah, N., & Alyaminy, I. H. A. Z. (2024). Development of blended learning-based e-learning to improve students' concept understanding in the COVID-19 pandemic era. *Journal of Research in Instructional*, *4*(1), 238–252. https://doi.org/10.30862/jri.v4i1.345

Karina, A., Sinaga, M., & Charlina, C. (2024). Developing teaching materials for writing observation report texts using Powtoon for grade X high school students. *Journal of Research in Instructional*, *4*(2), 345–358. https://doi.org/10.30862/jri.v4i2.425

Lee, W. W., & Owens, D. L. (2004). *Multimedia-based Instructional Design*. Pfeiffer.

Magdalena, I., Maemunah, S., Muawanah, M., & Astuti, I. (2021). Penggunaan Penilaian Teori Bloom dalam Pembelajaran Matematika di Kelas 3 SD Nurul Iman Ashopi. *Nusantara: Jurnal Pendidikan dan Ilmu Sosial*, *3*(2), 178-189. Retrieved from https://ejournal.stitpn.ac.id/index.php/nusantara/article/view/1237

Nwafor, S. C., Ibe, F. N., & Muoneke, N. M. (2022). Optimizing information and communication technology applications in chemistry learning. *Journal of Research in Instructional*, *2*(2), 151–162. https://doi.org/10.30862/jri.v2i2.92

Pratama, T. (2022). Aplikasi Pembelajaran Hewan Reptil Berbasis Augmented Reality. *Jurnal Informatika Dan Rekayasa Perangkat Lunak*, *3*(1), 73–76. https://doi.org/10.33365/jatika.v3i1.1862

Pringgar, R. F., & Sujatmiko, B. (2020). Penelitian Kepustakaan (Library Research) Modul Pembelajaran Berbasis Augmented Reality pada Pembelajaran Siswa. *J IT-Edu : Jurnal Information Technology and Education*, *5*(1), 317–329. https://doi.org/10.26740/it-edu.v5i1.37489

Putri, V. S., & Syafitri, Y. (2023). Dampak Perkembangan Teknologi Dalam Pendidikan Dimasa Pandemi Bagi Kaum Milenial. *Journal of Pedagogy and Online Learning*, *2*(1), 21–27. https://doi.org/10.24036/jpol.v2i1.20

Sa'diyah, I. S., Oktavia, R., Bisyara, R. S., & Badrudin. (2023). Implementasi Kurikulum

Merdeka Belajar Jenjang SMA. *Khazanah Multidisiplin*, *IV*(2), 348–362. https://doi.org/10.15575/kl.v4i2.28436

Sari, Y. (2023). Problem Oriented Project Based Learning Meningkatkan Hasil Belajar dan Kemampuan Berpikir Kritis Siswa Problem Oriented Project Based Learning to Improve Student's Learning Outcome and Critical Thinking Skills. *BIOMA: Jurnal Biologi Dan Pembelajaran Biologi*, *VIII*(1), 61–75. https://doi.org/10.32528/bioma.v8i1.361

Setyantoko, E., Nunaki, J. H., Jeni, J., & Damopolii, I. (2023). Development of human digestive system e-module to improve students' learning outcomes during pandemic. *AIP Conference Proceedings*, *2540*, 020002. https://doi.org/10.1063/5.0105782

Sugiyono, S. (2019). *Metodelogi Penelitian Kuantitatif dan Kualitatif Dan R&D*. Alfabeta.

Tang, Y., & Hew, K. F. (2022). Effects of using mobile instant messaging on student behavioral, emotional, and cognitive engagement: A quasi-experimental study. *International Journal of Educational Technology in Higher Education*, *19*(1), 3. https://doi.org/10.1186/s41239-021-00306-6

Zebua, E. (2023). Pengembangan Media Pembelajaran Audio Visual dengan Menggunakan Aplikasi Canva pada Materi Sistem Gerak. *BIOEDUSAINS:Jurnal Pendidikan Biologi Dan Sains*, *6*(2), 432–446. https://doi.org/10.31539/BIOEDUSAINS.V6I2.6916