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Improving Students' Visualization Concept through Augmented Reality Textbook in the Animal Respiratory System Material

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ABSTRACT
This research and development aims to produce a feasible textbook with Augmented Reality on the topic of respiratory organs in animals. Research and Development (R&D) is a research method that results in a product. The development method used refers to the Sadiman model. In its implementation, the textbook with Augmented Reality serves as a supplementary tool in the learning process, meaning this product is designed to complement teaching the topic of respiratory organs in animals. The results of the product feasibility tests conducted with media experts and subject matter experts, as well as field trials with students, show that the Augmented Reality product received positive responses, is feasible, and can be used in the learning process. Thus, it can be concluded that the Augmented Reality textbook can serve as a supplementary resource for students learning about animal respiratory organs, as its use can facilitate, motivate, and increase students' interest in the subject.

Keywords:
Teaching Materials, Augmented Reality, Natural Science

INTRODUCTION

Natural Sciences (IPA) at the Elementary School level faces significant challenges in teaching abstract material, such as anatomy or respiratory systems in animals, whose organs cannot be observed directly. Science learning at school is generally still based on printed books with two-dimensional images. However, the static presentation is not yet capable of supporting optimal visual and spatial understanding, because students must construct an individual mental representation of the object being studied. Conditions. This is reinforced by limitations on the use of tool props and concrete in class, so that students do not have direct experience with the objects studied. Using a picture flat in the book text demands that students mentally imagine a three-dimensional structure, which increases cognitive burden and can disturb understanding. In the material system of breathing animals, difficulties become more complex because students not only need to understand the shape and location of organs but also the mechanisms that operate dynamically and invisibly, such as gas exchange processes and airflow in animal bodies. In context, today's learners are more visual and interactive, using learning media, conventional static, and riskier approaches, with lower motivation and engagement.

Mayer (2020) in Cognitive Theory of Multimedia Learning confirms that meaningful learning happens when students select, organize, and integrate verbal and visual information simultaneously. If the media are limited to two-dimensional text and images, the selection and integration processes are burdensome for students. Cognitive Load Theory also emphasizes that human memory capacity is very limited, so instructional design must minimize extraneous burdens that are not needed (Sweller , 1988; Sweller et al., 2011) . With static media alone, students tend to feel overwhelmed and try to internalize concepts that aren't visible, which can lower focus and motivation to study.

Use of learning media in a general manner has benefits, namely: describing something so as not to impose too many verbal, overbearing limitations on time, space, and power senses, enhancing student motivation for active learning, giving new experiences to students, and allowing students to study independently in accordance with their abilities. Media is a tool that transmits information about the material shared by the teacher to students (Andriyani et al., 2020) . Learning through the media will make it easier for students to understand the material, as the availability of study materials helps them avoid boredom. This was also noted by Farhana et al., (2021), who stated that learning computer media has one advantage: it can increase motivation to learn, thereby making learning more effective.

Therefore, it is necessary to have innovative learning media that can provide visualization in a more concrete, interactive, and contextual way. One of the potential technology answers is Augmented Reality (AR), which allows integration between the real world and virtual objects in real-time, in the form of three-dimensional (3D) visualization. In science learning, AR can help represent abstract concepts as more concrete, making it easier for students to understand the connections between spatial and complex processes.

Technology Augmented Reality (AR) offers an innovative solution by combining real-world and virtual objects in an interactive and real-time manner, allowing for the visualization of three interactive and realistic (3D) dimensions of the structure, previously abstract and not visible to the eye (Soepriyanto & Ulfa, 2017) . The use of AR in printed teaching materials, such as AR-sensored books, can, in a way, significantly enrich students' experience by providing interactive 3D models that not only enhance visualization but also involve students in the learning process.

Various studies show that AR has the potential to increase understanding of complex, abstract science concepts in basic education. AR allows representation of three dimensions that drive student learning. For example, students can see objects from various angles, increasing the embodied learning aspect in which students' physiques interact and move during the learning process, thus deepening their understanding in ways that involve cognitive and motor skills (Mansour et al., 2025). The use of AR can also increase students' motivation and interest, providing a more engaging learning experience than conventional methods (Stojšić et al., 2022; Volioti et al., 2022).

A number of studies highlight that students respond positively to AR applications in learning biology and science, considering them useful and easy to use, which in turn increases participation and understanding of the material (Stojšić et al., 2022). In addition, AR is capable of bridging the limitations of physical tools at school, overcoming the costs and availability issues with traditional tools, and providing a realistic and actionable virtual model that can be interacted with directly by students (Bankar et al., 2024). Development of interoperable and integrated AR systems in curriculum schools is also getting bigger, making it easier to implement AR for learning, collaboratively and interactively in class (Masneri et al., 2022).

Although various studies have shown the potential of Augmented Reality to increase science learning, some large-scale studies still focus on developing AR applications for common use and have not yet been directly integrated into teaching materials, books, and texts used in everyday life. In fact, integration is important to ensure that technology can be used in a way that is contextual and sustainable in the environmental class. In addition, the AR design developed generally more focuses on visual and technical aspects, but Not yet in a way systematic referring to the principles learning cognitive, such as Cognitive Load Theory and Multimedia Learning Theory, so AR potential in optimizing cognitive processes students, in particular in reduce burden cognitive, not yet utilized in a way maximum.

Furthermore, AR development, specifically intended for visualizing the material systems of breathing animals at the level of schools, is still limited to a basic level, even though the material demands a higher level of abstraction that supports visualization and dynamic, contextual context. Therefore, it is necessary to develop Augmented Reality-based teaching materials that are not only innovative in terms of technology but also integrated with book text, designed based on the principles of cognitive learning, and focused on complex material characteristics, such as the breathing systems of animals.

A temporary challenge: technical and needs teacher training to adopt AR, a potential technology that increases visualization and engagement. Studies are still promising. The implementation of AR in printed teaching materials can be a breakthrough learning experience that overcomes abstraction, increases motivation, and helps students build a deeper, in-depth understanding of science through visual representations (Ali et al., 2021; Marín Rodriguez et al., 2023). Therefore, the implementation of AR in pedagogically designed print teaching materials becomes important. Not only to present innovative technology, but also to ensure its effectiveness in helping students build a deeper, more meaningful understanding.

To maximize the potential mentioned, it is necessary to approach implementation that is not only focused on technological aspects but also on suitable design learning that considers the characteristics of materials and the needs of cognitive students. Integration of Augmented Reality into printed teaching materials has become a relevant strategy because it maintains a familiar learning structure while enriching the experience through interactive visualization. With this approach to technology, it not only serves as a tool to help but also becomes an integral part of the designed learning process in a systematic and meaningful way.

Based on need said, research This aim for develop based teaching materials book integrated printing with Augmented Reality technology on materials system breathing animals at school basic. Development: This design is based on the principle of Cognitive Load Theory and Multimedia Learning. To minimize cognitive burden and increase students' understanding, motivation, and involvement in science learning.

Thus, integrating augmented reality technology into science education in schools can significantly support achievement, making learning more effective, enjoyable, and needs-oriented for today's digital-native students. This approach is also expected to serve as a bridge for schools with limited physical props, as well as to awaken students' enthusiasm for studying complex, abstract scientific material.

METHOD

This study uses Research and Development (R&D) methods to produce teaching materials in the form of a book with augmented reality and targets for development. This material covers the respiratory system in animals for fifth-grade students at SDN Purwantoro 7, Malang. The development model used is Sadiman's procedural model, which was chosen for its suitability to characteristics development teaching materials that emphasize systematic design instruction. This model has structured stages, from analysis of needs and formulation of the learning objective to development of the material and media evaluation, which allow products to be produced in harmony with students' needs and the characteristics of the material.

Although various development models, including modern iterative models, have been widely used in the development of digital technology, these models are generally more development-oriented for systems or complex, sustainable applications. In this context, focus mainly not on the development of the system device software in a repetitive way, but rather on integrating Augmented Reality technology into teaching materials, such as printed books, which requires a clear and focused channel design. Therefore, Sadiman's model is still considered relevant because it ensures that media development is not only aspect-oriented technology but also pedagogically suitable and learning-effective.

Procedure research and development in Sadiman's model consists of eight stages, namely: analyzing the needs and characteristics of students, formulating instructional objectives, formulating learning materials, compiling the success tool, writing the media script, production, evaluation/trial, and revision. Not all steps need to be done, as they adapt to the products that will be developed.

The following chart from the development model Sadiman:

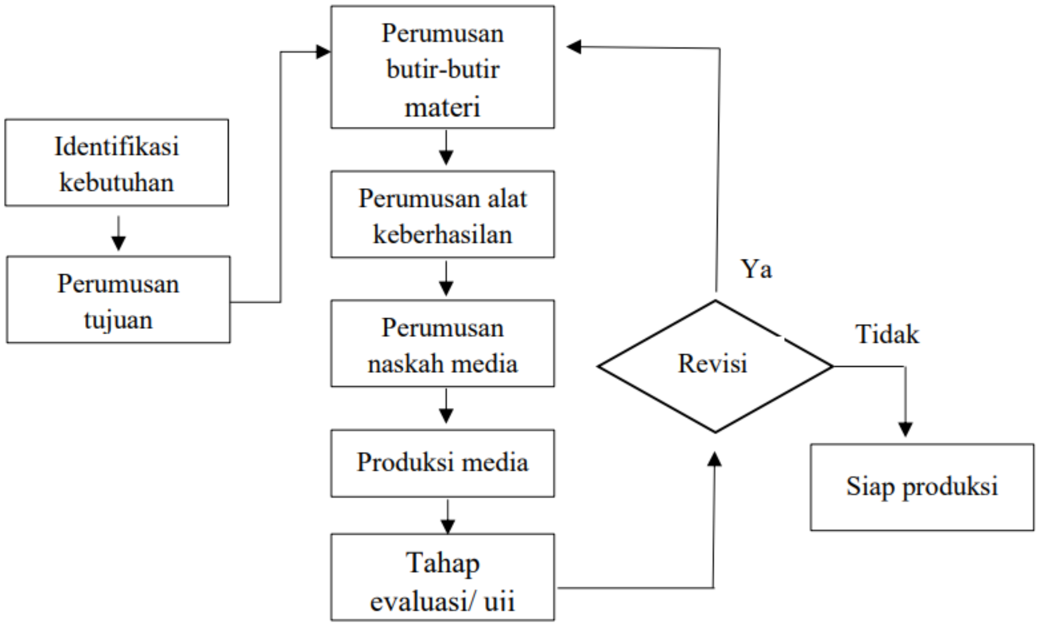

Figure 1. Sadiman development model's

Identification Need: This was done through method observation and interviews with teachers and principals, conducted by researchers at SDN Purwantoro 7 Malang, to gather information and identify problems in the learning process at the school.

Formulation of Objectives: At this stage, this formulation is crucial because it serves important goals. Objective learning is A reference to determine the process and expected success that happens after the learning activity. Learning objectives also serve as a basis for developers to create media that is expected to help students achieve the learning objectives that have been determined. The formulation involves analyzing Main Competencies (KI), determining Basic Competencies (KD), and compiling the objectives that you want to achieve.

Formulation Items of Material: At this stage, researchers develop appropriate material and content with KI, KD, and learning objectives, adapting to students' levels of thinking and using easy language that is understandable and appropriate for learning. In this matter, these researchers have already consulted with the fifth-grade teacher from SDN Purwantoro 7 Malang to develop a material tool for respiration in animals in the form of teaching materials books with augmented reality that contain the following materials: A definition of respiration in animals, various types of respiration in animals, and the system of respiration in animals.

Formulating Success Tools: In this stage, the objective is to achieve success at the known level by learning from using teaching materials in the form of a book, integrated with Augmented Reality, and to properly evaluate the required tools. The evaluation used is a pre-test/post-test. A pre-test is given before using teaching materials to measure the ability of beginning students, while the post-test is given after the learning process. For known improvement results, study the students. Instruments used in the form of multiple-choice questions, consisting of 20 multiple-choice questions, with each question worth 5, so the total score maximum is 100. The questions used in the pre-test and post-test are identical to ensure consistent measurement and improve results in the study.

Before being used in research, instruments are tested and evaluated for quality through validity and reliability tests. Validity test is conducted to determine the extent to which the grain question is capable of measuring expected competencies, which are validated by an expert (expert judgment). Temporarily, the reliability test aims to ensure the consistency of instruments, which can be generalized and quantified using a reliability coefficient, such as Cronbach's Alpha. In this study, the instrument was designed and validated by experts to meet the criteria for eligibility as a tool for measuring before being used in data collection. Aspects assessed in validation include suitable materials, construction questions, and clarity of language.

Formulation Media Script: In this stage, this formulation media script provides guidelines for manufacturing teaching materials in the form of an augmented-reality book. The script used is classified as visual or graphic in the form of a Storyboard display Application Alphabreaths and displays teaching materials in the form of a book, “Animal Respiratory System”.

Media Production: At this stage, the developer is designing books, 3D animations, and applications, using the necessary steps of pre-production, production, and post-production. Pre-production was conducted to create a storyboard for manufacturing augmented-reality teaching materials in book form and to determine the content of the teaching materials to be developed. And prepare the tools and materials required for the stage production. Production done with designing books, 3D animations, and applications used simultaneously. The required software: Blender for designing a 3D animation, Unity 3D for making an application, Barcode Maker for creating barcodes, and CorelDRAW X7 for designing a book layout. Post-production is a finishing process in which the method developer conducts a trial product in an independent way, using teaching materials in the form of a book with augmented reality, ready for use.

Evaluation /Testing: This is done through the design of a trial to be conducted with expert material, media experts, and the audience, which is the student Class V of SDN Purwantoro 7 Malang. Data types include quantitative and qualitative data, with instrument data analysis using questionnaire responses. Stage: This is done. For now, the eligibility product teaching materials are in the form of a book that utilizes Augmented Reality.

Revisions: At this stage, if in a previous stage there is criticism or suggestions from media experts, expert material will be prepared to address them based on each expert's evaluation. If all criticism and suggestions have been addressed, the media.At the stage This If in stage previously there is criticism or suggestions from media experts and expert material will done repair based on from evaluation from each expert, if all criticism and suggestions have been repaired, media teaching materials books with augmented reality ready used for implemented in a way direct to student Class V of SDN Purwantoro 7 Malang will get results from distribution questionnaire that will be will counted results end whether the teaching material media is in the form of book with this augmented reality Already worthy.

RESULTS AND DISCUSSION

The research and development produced an Augmented Reality Text product with the following appearance:

Figure 2. Display of teaching materials book integrated with AR

In research and development, a feasibility test was conducted with experts in their field to provide feedback on product teaching materials in the form of a book with Augmented

Reality. After the feasibility test process is carried out by experts, the products are tested by students to determine the success objective of developing Augmented Reality products.

The following is the results study of Augmented Reality Text products:

Table 1. Media expert validation results

Aspect Evaluation	Mean	Std. Dev	Criteria
Typography	4.00	0.00	Very Valid
Visual Design	3.80	0.42	Very Valid
AR Quality	4.00	0.00	Very Valid
Pedagogy	4.00	0.00	Very Valid
Interactivity	4.00	0.00	Very Valid
Average	3.96	0.20	Very Valid

Validation results show that a major aspect receives a maximum score, with an average of 4.00 and a standard deviation of 0.00, indicating a very high consistency rating. However, in the Visual design aspect, there are two points that earn a score of 3, so the average value across the aspects is 3.80 with a standard deviation of 0.42. Although thus, all aspects are still in the very valid category with an overall average of 3.96. This shows that developed teaching materials have fulfilled the eligibility criteria, are good in terms of appearance, Augmented Reality quality, and pedagogical aspects.

Table 2. Material expert validation results

Aspect Evaluation	Mean	Std. Dev	Criteria
Typography	4.00	0.00	Very Valid
Visual Design	4.00	0.00	Very Valid
AR Quality	4.00	0.00	Very Valid
Pedagogy	3.90	0.32	Very Valid
Interactivity	4.00	0.00	Very Valid
Average	3.98	0.14	Very Valid

Validation results from expert material show that of 48 grain assessments, 47 received a score of 4, and 1 received a score of 3. Overall average value of 3.98 with a standard deviation of 0.14, which shows a very high level of consistency. In the pedagogy aspect, there is one grain with a score of 3, so the average aspect value is 3.90. Although thus, all aspects are still in the very valid category . This shows that the material in the developed teaching materials aligns with objective learning and is suitable for use without major revision.

Trials were conducted on 8 students in class V of SDN Purwantoro as part of the small-group evaluation stage to obtain a description of the initial acceptability and potential effectiveness of the product. At this stage, the focus is on testing for generalization results and on identifying user responses, as well as on seeing trend improvement after using the product.

Based on the analysis of questionnaire responses from students, the obtained percentage of 90.8% indicates that Augmented Reality-based teaching materials are in the very good and suitable category for learning. In addition, the study's results show an improvement in existence. The pre-test score was 37.5%, and the post-test score was 87.5%. This indicates that Augmented Reality can enhance students' understanding of the material. However, given the limited number of subjects, these results cannot yet be generalized as proof of effectiveness on a wide scale. Therefore, it is necessary to study more samples, including larger, more representative ones, to test the effectiveness of a product comprehensively.

Use Augmented Reality-based teaching materials in study. This shows significant improvement in results. Study enough students, from pre-test scores of 37.5% to post-test scores of 87.5%. Increase. This not only shows success in a quantitative way but also indicates changes in students' cognitive processes during learning. In a way, theoretical findings. This can be explained through the Cognitive Theory of Multimedia Learning, which states that learning becomes more effective when information is served through a combination of visual and verbal cues simultaneously. In this matter, Augmented Reality allows students not only to read text in books but also to observe a three-dimensional representation of objects directly, which assists the integration of information into memory, making work more efficient. This aligns with the study (Ali et al., 2021; Rahmat et al., 2023) which shows that AR can enhance understanding of drafts through more concrete and interactive visualizations.

In addition, from a Cognitive Load Theory perspective, the use of AR in teaching materials can reduce cognitive burden, as is often apparent when students must imagine an abstract object from a two-dimensional image. Interactive 3D visualization allows students to understand the structure and mechanism in a more realistic way without having to engage in complex mental construction. This explains the improvement in students' understanding of the material system, beyond the previous animal-nature abstraction. Thus, AR not only functions as a tool for visual aid but also as a supporting facility for improving students' cognitive process efficiency in their studies.

From an affective perspective, the results indicate that students who achieve a 90.8% score perceive that the use of AR-based teaching materials provides an engaging experience and improves learning motivation. The interactivity provided by technology increases active students' involvement in learning, so that they not only become recipients of information but also play an active role as users directly interacting with the material. Findings. This strengthened results study (Khan et al., 2019) which states that AR can increase attention, satisfaction, and trust in students, as well as a study (Volioti et al., 2022) which shows that integrating visual and interactive elements in AR can increase acceptance and involvement of students in learning.

From a technical implementation perspective, the use of the marker-based tracking method in this teaching material is convenient, effective, and yields good results. The marker is designed with a high-contrast pattern (black and white), so it can be recognized by the smartphone camera and displays the object's three dimensions above it. Although relative marker size is proportional to page books, optimization of marker size and placement is still required to minimize the potential for lost tracking, especially in poor lighting or when scanning in corners. Thus, successful AR implementation is not only determined by pedagogical aspects but also by the quality of design, technical support, stability, and ease of use.

The results validation shows that a number of grains have assessment scores that are lower than those of other grains, especially in aspects such as visual design or presentation. This indicates that although the product, in a way, falls into a very valid category, it still requires improvements to several elements to make the experience study more optimal. Improvements in these aspects are expected to increase the quality of user interactions and the effectiveness of media in support of learning.

Development Hanan et al., (2018) about design teaching materials using augmented reality, next study conducted by Afdal et al., (2018) about 3D augmented reality for learning layer surface earth, research furthermore carried out by (Bakri et al., 2018) about development book learning material wave augmented reality- based sound and optics research furthermore conducted by (Ismail et al., 2020) about improvement competence professional teachers through training augmented reality- based teaching materials, next conducted by (Hafi & Supardiyono , 2018) about development book pocket augmented reality technology. Compared with previous studies, some large-scale studies on Augmented Reality still focused on developing applications as standalone learning media. Meanwhile, other research developed AR in various forms, such as pop-up books, book coloring, and as a supplement to digital learning (learning (Clark & Duenser , 2012; Vate -U-Lan, 2012; Weng et al., 2020).

In addition, the effectiveness of AR has also been proven in various fields, including science and medicine, for learning draft and training skills (Hughes-Hallett et al., 2014; Moro et al., 2017; Rhienmora et al., 2010). Different from the approach said, research. This integrates AR technology directly into teaching materials, such as printed books used in everyday learning. This is more contextual and easier to implement in schools, especially in conditions with limited technological facilities.

However, some limitations of the study should be noted when interpreting the results. First, the number of test subjects, which involves only 8 students, is still at the small-group evaluation stage, so the results of this study cannot yet be generalized to a wider population. Limitations of the sample size. This has implications for low data representativeness against a larger population. Second , research. This has not yet been used in a group control group, so the learning improvement cannot yet be fully attributed to the augmented reality teaching materials. Other factors, such as motivation, study, and the novelty effect, can also influence research results. Third, from a technical perspective, marker-based tracking still has limitations related to sensitivity to lighting conditions, angle scanning, and the quality of the camera devices used by students, which can cause tracking to be lost under certain conditions.

Based on the limitations mentioned, the research further recommended conducting a larger-scale trial, involving more representative samples, and using a stronger experimental design, such as a quasi-experimental or true experimental design with a group control. In addition, the development of AR technology can focus on method markerless tracking or marker-optimized design to be more adaptive to various use conditions. Research continuation is also important to explore the long-term impact of Augmented Reality on retention of knowledge, skills, and critical thinking, as well as on students' involvement in various learning contexts.

Thus, the results of this study not only strengthen previous findings on the effectiveness of Augmented Reality in learning but also contribute to the integration of digital technology and conventional teaching materials. This integration allows the creation of a more interactive, contextual, and appropriate learning experience for basic school students, while at the same time bridging the gap between the needs of modern learning and the limitations of educational facilities.

CONCLUSION

Based on the results, the due diligence responses from media experts and the experts' materials, the products developed were deemed very suitable for use in learning. This is based on the results assessment, which shows 99% of media experts and 99.5% of expert materials, as well as trial results for students, which show 90.8%. Based on criteria that have been established, the development of teaching materials, books, and Augmented Reality-based material tools for breathing animals. This is stated to be feasible and effective.

More specifically, the findings have important implications for science learning, particularly in facilitating understanding of abstract and complex concepts. Integration of Augmented Reality into a book allows students to visualize the system structure and processes of a breathing animal in a three-dimensional, interactive way, so that the previously difficult concept, presented through a two-dimensional image, becomes more concrete and easier to understand. With this, the book AR not only functions as a source of learning but also as a medium of transformational concept, which helps students build a greater understanding, improve motivation for learning, and strengthen student involvement in the learning process.

REFERENCES

Afdal, M., Irsyad, M., & Yanto, F. (2018). Implementation augmented reality technology in learning media layer surface earth 3D- based *Journal Engineering and Management Science System Information*, *4* (1), 1–10.

Ali, DF, Omar, M., Abdullah, AH, Ibrahim, NH, Mokhtar, M., Mohd Zaid, N., & Johari, N. (2021). 5 Years into Augmented Reality Technology in Education: Research Trends, Bibliometric Study and its Application to Enhance Visualization Skills. *WSEAS TRANSACTIONS ON SYSTEMS AND CONTROL* , *16* , 253–260. https://doi.org/10.37394/23203.2021.16.21

Andriyani, A., Dewi, HI, & Zulfitria , Z. (2020). Use of multimedia and animation interactive to skills read beginning Students . *Instructional* , *1* (2), 172–180.

Bakri, F., Ambarwulan , D., & Muliyati , D. (2018). Development book learning equipped with augmented reality at its core discussion wave sound and optics . *Gravity: Journal Scientific Physics Research and Learning* , *4* (2). https://jurnal.untirta.ac.id/index.php/Gravity/article/view/4205

Bankar, M.N., Bankar, N.J., Gajbe , U., Singh, B., Mishra, V.H., Bahadure , S., Bandre , G.R., Bankar, S.N., & Shelke, Y.P. (2024). A narrative literature review on new technologies for teaching anatomy. *International Journal of Academic Medicine* , *10* (2), 47–55. https://doi.org/10.4103/ijam.ijam_30_24

Clark, A., & Duenser , A. (2012). *(PDF) An interactive augmented reality coloring book* . https://www.researchgate.net/publication/261483177_An_interactive_augmented_reality_coloring_book

Farhana, S., Magdalena, I., & Safitri , A. (2021). Teacher Strategies in Increase Quality Teaching During the COVID-19 Pandemic . *Cerdika : Journal Indonesian Science* , *1* (3), 313–320.

Hafi, NN, & Supardiyono , S. (2018). Development book pocket physics with Android- based Augmented Reality technology on the material global warming . *Innovation in Physics Education* , *7* (2).

Hanan, RA, Fajar, I., Pramuditya , SA, & Noto, MS (2018). Augmented Reality -Based Teaching Material Design for Plane Space Material . *Proceedings of the National Seminar* on *Mathematics and Mathematics Education (SNMPM)* , *2* (1), 287–299.

Hughes-Hallett, A., Mayer, E.K., Marcus, H.J., Cundy, T.P., Pratt, P.J., Darzi, A.W., & Vale, J.A. (2014). Augmented reality partial nephrectomy: Examining the current status and future perspectives. *Urology* , *83* (2), 266–273.

Ismail, A., Nasrulloh , I., & Gumilar , S. (2020). Improvement competence professional physics teacher vocational education in the Regency Garut through training development Augmented reality- based teaching materials . *Proceedings of the National Seminar on Community Service, Ma Chung University* . https://ocs.machung.ac.id/index.php/senam/article/view/28

Khan, T., Johnston, K., & Ophoff, J. (2019). The Impact of an Augmented Reality Application on Learning Motivation of Students. *Advances in Human-Computer Interaction* , *2019* , 1–14. https://doi.org/10.1155/2019/7208494

Mansour, N., Aras, C., Staarman , J. K., & Alotaibi, S. B. M. (2025). Embodied learning of science concepts through augmented reality technology. *Education and Information Technologies* , *30* (6), 8245–8275. https://doi.org/10.1007/s10639-024-13120-0

Marín Rodriguez, WJ, Andrade Girón, DC, Zúñiga Rojas, ZR, Susanibar Ramirez, ET, Calvo Rivera, IP, Ausejo Sanchez, JL, & Caro Soto, FG (2023). Artificial Intelligence and Augmented Reality in Higher Education: A systematic review. *Data and Metadata* , *2* , 121. https://doi.org/10.56294/dm2023121

Masneri , S., Domínguez, A., Sanz, M., Zorrilla, M., Larrañaga, M., & Arruarte , A. (2023). cleAR : An interoperable architecture for multi-user AR-based school curricula. *Virtual Reality* , *27* (3), 1813–1825. https://doi.org/10.1007/s10055-023-00764-5

Masneri , S., Domínguez, A., Zorrilla, M., Larrañaga, M., & Arruarte , A. (2022). Interactive, Collaborative and Multi-user Augmented Reality Applications in Primary and Secondary Education. A Systematic Review. *JUCS - Journal of Universal Computer Science* , *28* (6), 564–590. https://doi.org/10.3897/jucs.76535

Mayer, R.E. (2020). *Multimedia Learning.* https://www.google.com/search?q=Mayer%2C+R.+E.+%282020%29.+Multimedia+Learning.+Cambridge+University+Press.&sca_esv=d13727888d1d456a&sxsrf=ADLYWIJg6YeVUnHOOYWCXXtU9L57UhztwA%3A1730701766265&ei=xmkoZ9P2DuuQseMPnKzUiAI&ved=0ahUKEwjT8fS_hsKJAxVrSGwGHRwWFSEQ4dUDCA8&uact=5&oq=Mayer%2C+R.+E.+%282020%29.+Multimedia+Learning.+Cambridge+University+Press.&gs_lp=Eg xnd3Mtd2l6LXNlcnAiRU1heWVyLCBSLiBFLiAoMjAyMCkuIE11bHRpbWVkaWEgTGVhcm5pbmcuIENhbWJyaWRnZSBVbml2ZXJza XR5IFByZXNzLkgAUABYAHAAeACQAQCYAQCgAQCqAQC4AQPIAQD4AQL4AQGYAgCgAgCYAwCSBwCgBwA&sclient=gws-wiz-serp

Moro, C., Štromberga , Z., Raikos , A., & Stirling, A. (2017). The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anatomical Sciences Education* , *10* (6), 549–559. https://doi.org/10.1002/ase.1696

Rahmat, AD, Kuswanto , H., Wilujeng , I., & Perdana, R. (2023). Implementation of mobile augmented reality on physics learning in junior high school students. *Journal of Education and E-Learning Research* , *10* (2), 132–140. https://doi.org/10.20448/jeelr.v10i2.4474

Rhienmora , P., Gajananan, K., Haddawy , P., Dailey, M.N., & Suebnukarn , S. (2010). Augmented reality haptics system for dental surgical skills training. *Proceedings of the 17th ACM Symposium on Virtual Reality Software and Technology* , 97–98. https://doi.org/10.1145/1889863.1889883

Sadiman, AS (2010). Educational Media, Jakarta: PT. *Raja Grafindo Persada* .

Soepriyanto , Y., & Ulfa , S. (2017). Development of Augmented Reality as an Electronic Performance Support System in Learning . *Edcomtech : Journal of Educational Technology Studies* , *2* (1), 1–10.

Stojšić , I., Ostojić, N., & Stanisavljević , J. (2022). Students' Acceptance of Mobile Augmented Reality Applications in Primary and Secondary Biology Education. *International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE)* , *10* (3), 129–138. https://doi.org/10.23947/2334-8496-2022-10-3-129-138

Sweller , J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science* , *12* (2), 257–285.

Sweller , J., Ayres, P., & Kalyuga , S. (2011). Altering Element Interactivity and Intrinsic Cognitive load. In J. Sweller , P. Ayres, & S. Kalyuga , *Cognitive Load Theory* (pp. 203–218). Springer New York. https://doi.org/10.1007/978-1-4419-8126-4_16

Vate -U-Lan, P. (2012). An augmented reality 3d pop-up book: The development of a multimedia project for English language teaching. *2012 IEEE International Conference on Multimedia and Expo* , 890–895. https://ieeexplore.ieee.org/abstract/document/6298515/

Volioti , C., Keramopoulos , E., Sapounidis, T., Melisidis , K., Zafeiropoulou, M., Sotiriou, C., & Spiridis , V. (2022). Using Augmented Reality in K-12 Education: An Indicative Platform for Teaching Physics. *Information* , *13* (7), 336. https://doi.org/10.3390/info13070336

Weng, C., Otanga , S., Christianto, SM, & Chu, RJ-C. (2020). Enhancing Students' Biology Learning by Using Augmented Reality as a Learning Supplement. *Journal of Educational Computing Research* , *58* (4), 747–770. https://doi.org/10.1177/0735633119884213