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Development of Augmented Reality-Based Science Module to Find Out the Understanding of Grade IX Junior High School Students on Pressure Concepts

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Abstract: This study aims to develop an Augmented Reality (AR)-based science module to improve students' understanding of pressure concepts. The development was motivated by students' low interest and difficulty in learning abstract pressure concepts, as well as the limited availability of interactive instructional media. The research employed the ADDIE development model and implemented a one-group pretest–posttest design to evaluate the module's effectiveness. The AR module was designed based on curriculum requirements and student characteristics, followed by the creation of 3D visualizations and integration into an AR application. Validation by material and media experts indicated a very good level of feasibility (mean score 4.78 on a 5-point scale). The module was implemented with Grade IX students at SMP Surya Kencana Bhakti, Bandung. Results showed an increase in the average score from 36.79 (pretest) to 75.71 (posttest). The normalized gain (N-gain) was 0.62, which falls into the Medium category according to Hake's criteria. The improvement was statistically meaningful, and more than 90% of students reported higher motivation and engagement. Overall, the AR-based module is considered feasible and effective, making it a suitable interactive learning resource for supporting science learning in the 21st century.

Keywords: Augmented reality; Digital module; Pressure

Introduction

Education is a systematic process aimed at enhancing individuals' skills, attitudes, and behaviors so they can contribute meaningfully to themselves, their environment, and society. Education not only involves the transfer of knowledge but also integrates social, political, cultural, and religious dimensions essential to human life. In the era of globalization, education plays a crucial role in improving the quality of human resources to compete and adapt to rapid global changes (Badrudin, 2024). According to Indonesian Law Number 20 of 2003 on the National Education System, Article 3, national education functions to develop capabilities and form a dignified national character as well as to educate the nation. Its goal is to develop learners' potential so they become individuals who believe in and fear God Almighty, possess noble character, are healthy, knowledgeable, competent, creative, independent, and become democratic and responsible citizens. Therefore, educators are required to design, implement, and evaluate learning in an effective and innovative manner (Mundir, 2022).

The rapid technological advancements brought by the Industrial Revolution 4.0 and Society 5.0 have significantly transformed the educational landscape. Society 5.0 emphasizes the integration of advanced technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Augmented Reality (AR) into various aspects of life, including education (Zahara, 2023). The shift in lifestyle that prioritizes flexibility, efficiency, and effectiveness demands that educational practices adapt quickly (Saputra, 2021). These technologies enable more dynamic, interactive, and

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effective learning experiences, thereby improving educational quality (Setiawan, 2023). However, challenges persist in technology implementation. Many teachers still encounter technical barriers, such as limited ability to design digital learning media, inadequate visual design skills, and minimal programming knowledge (Prananta et al., 2024). As a result, digital media often replicate printed materials without meaningful interactivity, making learning less engaging and more difficult to comprehend particularly for abstract topics such as pressure in Natural Sciences.

Observations at SMP Surya Kencana Bhakti, Bandung indicate that students show low interest in printed textbooks due to dense text and lack of interactivity. Students prefer learning materials that are more engaging, easy to understand, and able to provide enjoyable learning experiences. The topic of pressure covering pressure in solids, liquids, and gases is considered challenging because of its abstract nature and the limited availability of supporting teaching aids. To address these issues, the development of digital learning modules based on AR technology presents a strategic solution. AR-based modules can offer interactive 3D visualizations that help students understand abstract concepts more effectively. Previous research has shown that AR improves comprehension, motivation, and scientific literacy (Iatraki & Mikropoulos, 2022) and minimizes misconceptions through clear and appealing visual representations (Koumpouros, 2024).

Augmented Reality is a technology that integrates virtual 2D or 3D objects into real environments in real time (Nurhidayanti et al., 2022; Adji et al., 2023). AR can be accessed via smartphones using Android or iOS operating systems, making it compatible with current digital learning strategies. Learning environments enriched with real-world context and interactivity help learners organize and retain information more effectively. AR provides immersive learning experiences, making learning more meaningful (Yilmaz, 2021). By enhancing spatial and temporal understanding, AR allows learners to observe, hear, and interact with representations of physics concepts especially those that are challenging to explain through theory or static images alone (Lai & Cheong, 2022). Marker-based tracking enables precise interaction with virtual environments (Rofi'i et al., 2023), while AR technology works fundamentally by merging image data with video streams from devices such as webcams (Nincarean et al., 2019). In educational contexts, AR applications make learning more interactive and engaging, fostering student interest and participation. AR also enhances literacy skills reading, writing, speaking, and listening by encouraging active involvement. The Alpha generation, who are highly familiar with digital technologies, benefit significantly from AR-based media that support their technological competencies (Hafizah, 2023).

The use of Augmented Reality (AR) in learning stimulates students' critical thinking in understanding everyday phenomena and encourages them to analyze problems creatively and participate actively in the learning process (Mubarok et al., 2020). When integrated with the Problem Based Learning (PBL) model, AR is able to attract students' attention, increase student involvement in the learning process, and train students' critical thinking skills in solving contextual problems (Retiyanto et al., 2023; Nafi'ah & Asih, 2024). Empirical evidence also shows that students who learn through PBL supported by AR media achieve better learning outcomes than those taught using conventional lecture methods and are able to meet minimum learning mastery criteria (Sapira et al., 2023). Several studies have reported that the integration of AR with PBL improves learning outcomes and students' attitudes toward physics learning. Fidan and Tuncel demonstrated that marker-based AR (FenAR) effectively supports students' thinking processes and problem understanding in learning activities (Fidan & Tuncel, 2019). In addition, Kholiq's research on the development of an AR-based physics digital book (BDF-AR2) showed that AR-based learning media effectively enhance students' scientific literacy and support the demands of 21st century learning (Kholiq, 2020).

A synthesis by Sebastian and Kuswanto of studies from 2017 to 2022 reveals that AR in physics education is primarily applied to mechanics and electricity topics through experiments and application-based learning. AR enhances various cognitive abilities, including self-efficacy, conceptual understanding, critical and higher-order thinking, visual representation, abstract reasoning, scientific literacy, creativity, computational thinking, and problem solving. It also supports students' affective development and optimizes learning outcomes (Sebastian & Kuswanto, 2024; Milasari & Setyasto, 2023). Meanwhile, Dolenc et al. developed the ARphymedes application, designed to present 3D representations of physical objects or concepts, such as floating, sinking, and suspended objects in fluids. Concepts related to Archimedes' law such as fluid pressure, submerged volume, and density are often difficult for students to visualize, making AR an effective medium for explaining such concepts (Dolenc et al., 2024). Archimedes' law is particularly suitable for AR applications because its real-world manifestations such as ships, submarines, and hot-air balloons are commonly encountered in daily life.

Based on the above explanation, the development of AR-based learning materials for the topic of pressure is urgently needed. This study aims to develop an AR-based digital science module and assess grade IX students' understanding of the concept of pressure. The resulting module is expected to contribute to the development of innovative digital learning resources aligned with the needs of 21st century education.

Method

This study employed a research and development (R&D) approach using the ADDIE model Analysis, Design, Development, Implementation, and Evaluation, as a systematic framework for instructional design (Branch, 2009; Sugiyono, 2016). In the analysis phase, the researchers conducted a needs analysis to evaluate the availability of existing learning resources, a curriculum analysis to ensure alignment with educational standards, and a learner analysis to identify students' needs and characteristics. The design phase involved planning the AR-based digital module, structuring its content, and collecting relevant references. During the development phase, 3D models were created using Paint 3D, annotated through Sketchfab, and integrated with audio elements using the WorldCast application. Canva was used for interactive visual design, and Google Forms was utilized to collect student feedback.

The digital module was then validated by a media expert, a subject matter expert, and a science teacher as a practitioner. The implementation phase involved a trial with Grade IX students at SMP Surya Kencana Bhakti, using a one-group pretest-posttest experimental design to assess learning outcomes. An evaluation was conducted by analyzing students' feedback to guide the final revision of the module. Data collection techniques included observation, expert validation sheets, student response questionnaires, and pretest-posttest assessments.

Data analysis methods included validity testing using mean score calculations, practicality analysis using percentage scores, and effectiveness analysis through normalized gain (N-gain). The N-gain score was calculated using the following equation:

$$\text{N-gain} = \frac{(\text{Posttest score} - \text{Pretest score})}{(\text{Maximum score} - \text{Pretest score})} \quad (1)$$

This formula measures the relative improvement in students' understanding after the intervention, normalized to the maximum possible improvement. N-gain values are commonly categorized as high ($g \geq 0.7$), medium ($0.3 \leq g < 0.7$), and low ($g < 0.3$) (Hake, 1998).

Result and Discussion

The Augmented Reality-based science module was developed using the ADDIE instructional design model (Analysis, Design, Development, Implementation, Evaluation). The analysis revealed that students had difficulty understanding the concept of pressure, due to its abstract nature. Therefore, a visual and interactive medium was deemed necessary. The design phase involved structuring the module based on the expected learning outcomes and the characteristics of the subject matter. The module was designed to include explanatory content, illustrative images, student activities, and Augmented Reality elements integrated through links or QR code scanning. The visual design of the module was developed using templates from Canva to ensure an attractive, user-friendly layout, as illustrated in Figure 1.

Figure 1. Cover view of science module on pressure concepts

The development phase encompassed the creation of the AR-based digital module, which began with the adaptation and modification of 3D objects sourced from the Paint 3D library. These objects were annotated using Sketchfab, followed by the design of the module using Canva for visual layout and WorldCAST for AR object generation. The module was developed with reference to the expected learning outcomes and the standardized structure of instructional content. It was systematically organized into sections, including an introduction, content presentation, AR-based exploratory activities, and final evaluation. More comprehensively, the module includes learning objectives, user instructions, an integrated attendance link via Google Forms, core material, sample problems, practice exercises, both 2D and 3D visualizations, and interactive quizzes.

The integration of an attendance link via Google Forms, as illustrated in Figure 2, functions not only as a means of recording student participation but also supports efficient data collection for instructional planning and evaluation. This strategy is consistent with digital learning best practices in which cloud-based platforms such as Google Forms streamline administrative tasks and facilitate learning analytics. As noted by Alim et al. (2019), the application of Google Forms in educational settings enables real-time data acquisition, enhances teacher–student communication, and simplifies documentation procedures. Additionally, it fosters student responsibility by requiring attendance confirmation prior to engaging with the learning materials.

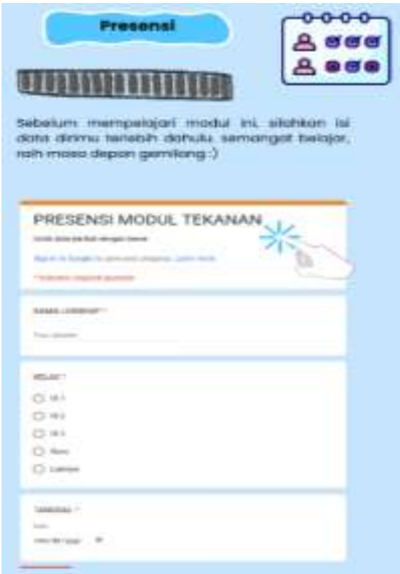

Figure 2. Integration of attendance link via google forms

The core material of the module is designed to promote conceptual understanding through contextual and relatable examples. As illustrated in Figure 3, the concept of pressure is introduced through a simple everyday activity slicing an apple which highlights the influence of surface area and force on pressure. This real-world scenario is intended to engage students and connect abstract scientific principles with familiar experiences. This approach aligns with the Merdeka Curriculum framework, which emphasizes meaningful, experiential, and student-centered learning (Kemendikbudristek, 2022). The Merdeka Curriculum encourages learners to construct understanding through real-life contexts while providing educators with the flexibility to design adaptive instructional strategies (Nurjaman & Putra, 2023).

Research indicates that contextual, problem-based science instruction in accordance with the Merdeka Curriculum enhances student engagement, creativity, and learning outcomes (Nurjaman & Putra, 2023). Furthermore, the inclusion of interactive features, such as 2D and 3D visualizations and quizzes, reinforces the learning process and supports differentiated instruction, a key component of the curriculum's competency-oriented goals (Kemendikbudristek, 2022).

Figure 3. A contextual example of the concept of pressure

Sample problems in physics learning modules serve as an essential bridge between theoretical understanding and practical application. As illustrated in Figure 5, students are engaged in a contextual problem-solving activity involving plasticine to investigate the phenomena of floating, hovering, and sinking. This activity not only reinforces conceptual understanding but also fosters critical thinking skills through hands-on experience.

Figure 4. Contextual sample problem using plasticine to explore buoyancy

Previous researchers emphasized that Integrating problem-based learning (PBL) sample problems into digital modules significantly enhances students' science process skills. For example, students investigate how the shape of plasticine affects its buoyancy, which indirectly reinforces their understanding of pressure and density concepts (Doyan et al., 2020; Serevina et al., 2018). Furthermore, interactive and contextual sample problems have been shown to effectively promote students' critical thinking skills. As illustrated in Figure 5, by engaging students in observation and exploration, the learning process becomes more meaningful and applicable to real-world contexts (Sari et al., 2020).

Thus, practice exercises play a crucial role in physics learning modules by reinforcing conceptual understanding and fostering critical thinking as shown in Figure 6. These exercises encourage students to apply theoretical knowledge in diverse and practical contexts. Presenting information in real-world contexts, like pressure applications, enhances student engagement and motivation, making learning more meaningful and effective.

Figure 5. Visualization of a 3D ship object (modified from the Sketchfab library)

Figure 6. Visualization of a 3D ship object

Figure 6 shows an example of a 3D object visualization in the form of a ship. The module is also accessible via the link (https://shorturl.at/aKvkY), providing an alternative for users who may not have access to a device or additional tools for QR code scanning.

The integration of AR technology within the module is facilitated through QR code scanning, which directs users to digital objects relevant to the subtopics, accompanied by audio-based explanations. Figure 8 illustrates AR visualization of a ship, allowing students to interact with the object by zooming in or rotating it, thereby enhancing their understanding of structural details beyond conventional 2D representations. The performance of AR applications is highly dependent on hardware specifications such as RAM, Android version, and camera quality. Surreal Bytes recommends a minimum specification of Android 7.0 or iOS 11.0, a quad-core 1.4 GHz processor, 2 GB RAM, an 8 MP rear camera, gyroscope, accelerometer, and a 720p display. Google provides a list of ARCore-certified devices that typically meet these criteria (https://developers.google.com/ar/devices?hl=id).

Figure 7. Augmented reality visualization of a ship object

Devices with higher specifications tend to deliver smoother and more responsive AR experiences (Ali, 2022), while those with lower specifications may exhibit noticeable differences in performance and visual quality (Verykokou, 2021). Furthermore, mobile AR applications have been found to be CPU intensive and generate higher thermal output compared to non-AR applications, potentially affecting both performance and user comfort (Chen, 2018).

Figure 9 presents the display of an interactive quiz designed to assess students' understanding of key concepts previously studied, such as solid pressure, liquid pressure, and related laws, including Pascal's law and Archimedes' principle.

The quiz interface features a visually appealing design with a combination of contrasting yet user-friendly colors. The questions are presented in a multiple choice format and are accompanied by real-time feedback that appears immediately after a student selects an answer, indicating whether the response is correct or incorrect. The interactivity of the quiz is further enhanced through the use of illustrative images, enabling students to comprehend the questions not only through text but also through visual representation.

Figure 8. Display of the interactive quiz interface

Table 1. Expert Validation Results for Augmented Reality Module

Expert	Score	Category
Conten expert	4.85	Very good
Media expert	4.70	Very good
Practitioner	5.00	Very good

Expert validation results demonstrated that the module is highly valid. Based on Table 1, content experts awarded a score of 4.85, while media experts gave a score of 4.70, both falling into the "very good" category. Additionally, teachers provided a perfect score of 5.00. Based on the feedback, revisions were made to improve image aesthetics and clarify terminology. Following these improvements, the module was confirmed to align with the Learning Outcomes and Learning Objectives. All elements within the module were clearly and accurately arranged. An effective learning criterion is the use of media that meets students' needs and supports the achievement of learning objectives (Siregar, 2022). Moreover, the module's components were systematically, simply, and clearly organized, supported by illustrative images and 3D visualizations that facilitate student comprehension. The module also met standards in content structure, systematic presentation, and communicative language use.

Thus, systematically structured components of learning materials, including learning outcomes, objectives, and detailed content, aid students in better understanding the subject matter. From a linguistic perspective, the module complies with the Enhanced Spelling System, employs communicative language that is easy to read, avoids ambiguity, and is overall accessible for students. Communicative language refers to the appropriate use of language functions in communication to ensure that messages are easily comprehended by readers (Yastini et al., 2018).

The findings of this study are consistent with those reported by Ziden (2022), who stated that active interaction based learning, including the use of technological media such as Augmented Reality, can significantly enhance students' learning outcomes. This is reflected in the average N-gain scores, which generally fall within the medium to high category. The relatively even improvement in learning outcomes among students in this study also supports the findings of Billinghurst et al. (2012), who concluded that AR-based books integrating textual content with interactive elements have considerable potential to enhance learning effectiveness, particularly for students with low literacy skills. Their study revealed that in text- based sections, students with higher abilities were able to recall significantly more material compared to those with lower abilities. Conversely, in interactive AR-based sections, no significant differences were found between the two groups in terms of material retention. These findings suggest that the interactivity provided by AR media can serve as a leveling factor in the learning process, offering more equitable learning opportunities for students with diverse literacy levels (Ropawandi et al., 2023).

Thus, the use of AR in education not only facilitates the visualization of abstract concepts in a more concrete manner but also contributes to narrowing the comprehension gap among students with varying initial abilities. This highlights the potential of AR as an inclusive and effective instructional medium that supports optimal learning outcomes for all students.

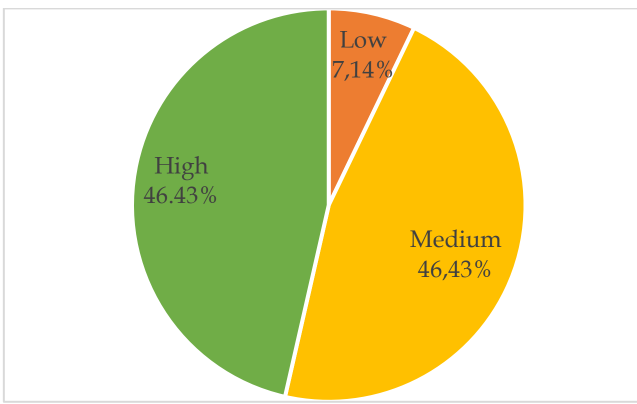

Figure 9. Distribution of N-gain categories

Effectiveness testing was conducted on 28 grade IX students using a pretest–posttest design as shown in Figure 9 the average pretest score was 36.79, which increased to 75.71 in the posttest. The normalized gain (N-gain) was 0.62, categorized as medium.

Furthermore, 46.43% of students showed high improvement, 46.43% showed medium improvement, and 7.14% showed low improvement. These findings indicate that the AR-based module effectively improved students' conceptual understanding of the topic.

In addition, the variability in N-gain results indicates that the module's impact may vary depending on each student's learning readiness and learning style. For instance, students with higher pretest scores tended to show lower N-gain values due to the limited room for improvement. Conversely, students with lower pretest scores generally experienced significant increases in their N-gain after the learning intervention. Overall, these data suggest that the AR-based module is both feasible and effective as a learning medium, as it significantly enhances student learning outcomes. These results are consistent with expert validations from content and media specialists, as well as positive feedback from teachers, who rated the module as excellent in terms of content quality, language clarity, usefulness, and ease of use. The improvement in learning outcomes also reflects the AR module's ability to attract students' attention and increase their motivation to learn particularly due to the visual and interactive approach it offers.

As shown in Figure 10, students were engaged in using AR technology by zooming in and rotating 3D objects on their mobile screens. This activity illustrates direct student involvement in exploring 3D visual objects, providing a more concrete and enjoyable learning experience that facilitates the understanding of abstract concepts.

Figure 10. Students using augmented reality technology

Student feedback indicated high levels of satisfaction. All students (100%) expressed enjoyment in using the module, and 93% felt more confident in learning. Additionally, 100% reported increased motivation. AR elements were considered easy to use, with only minor technical issues (21%) related to loading time and connectivity. The interactive nature of the module enhanced students' engagement and supported a learner centered environment. The positive feedback and practical implementation suggest that AR-based modules can enrich science instruction and support 21st century learning.

Conclusion

Based on the results of the research and development conducted, it can be concluded that the Augmented Reality based module for the topic of pressure in Grade IX junior high school is feasible and effective for use in the learning process. The module's feasibility is evidenced by expert validation results, with a score of 4.85 from content experts and 4.70 from media experts, both falling into the very good category. The module meets the criteria for content quality, presentation, and technical aspects, in accordance with instructional media development standards. In addition, the teacher response questionnaire, which scored 5.00, indicates that the module is practical, easy to use, and highly beneficial for supporting the learning process. In terms of effectiveness, the implementation of the module significantly improved students' conceptual understanding, with the average pretest score increasing from 36.79 to 75.71 in the posttest. The normalized gain (N-gain) score of 0.62 is categorized as medium, with 46.43% of students showing high improvement, 46.43% medium, and 7.14% low. The pretest score (36.79 ± 15.13) reflects the variation in students' initial abilities, while the posttest score (75.71 ± 15.04) indicates a significant improvement with more homogeneous learning outcomes. Beyond enhancing learning achievement, the AR-based module also proved to increase students' engagement, motivation, and self-confidence. Most students reported feeling happy, active, and found it easier to understand the material after using the module. The interactive visualization features of AR technology played a major role in clarifying abstract scientific concepts and improving the quality of science learning. Therefore, the Augmented Reality-based module developed in this study serves as an innovative learning media alternative that supports visual, interactive, and contextual learning, in alignment with the demands of 21st century education.

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Author Contributions
Conceptualization, methodology, validation, formal analysis, investigation, resources; S.; data curation, writing—original draft preparation, writing—review and editing, visualization, I. A. All authors have read and agreed to the published version of the manuscript.

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The author declares no conflict of interest in this research.

References

Adji, S. S., Masbukhin, F. A. A., & Wathi, A. F. D. (2023). Student Response in Using Smartphone-Assisted Augmented Reality Video in Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11551–11559. https://doi.org/10.29303/jppipa.v9i12.5921

Alim, N., Linda, W., Gunawan, F., & Saad, M. S. M. (2019). The effectiveness of Google classroom as an instructional media: A case of state islamic institute of Kendari, Indonesia. *Humanities and Social Sciences Reviews*, *7*(2), 240–246. https://doi.org/10.18510/hssr.2019.7227

Apriyanto, F. (2022). Peran Generasi Muda Terhadap Perkembangan Teknologi Digital Di Era Society 5.0. *Media Husada Journal Of Community Service*, *2*(2), 130–134. https://doi.org/10.33475/mhjcs.v2i2.35

Badrudin, B., Setiana, R., Fauziyyah, S., & Ramdani, S. (2024). Standarisasi Pendidikan Nasional. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *7*(2), 1797–1808. https://doi.org/10.54371/jiip.v7i2.3962

Billinghurst, M., & Dünser, A. (2012). Augmented reality in the classroom. *Computer*, *45*(7), 56–63. https://doi.org/10.1109/MC.2012.111

Branch, R. M. (2009). *Instructional Design-The ADDIE Approach*. New York: Springer.

Chen, H., Dai, Y., Meng, H., Chen, Y., & Li, T. (2018). Understanding the Characteristics of Mobile Augmented Reality Applications. *2018 IEEE International Symposium on Performance Analysis of Systems and Software (ISPASS)*, 128–138. https://doi.org/10.1109/ISPASS.2018.00026

Dolenc, S., Susman, K., & Pavlin, J. (2024). Usage of Augmented Reality in Physics Education: Erasmus+ KA201 Project ARphymedes. *Journal of Physics: Conference Series*, *2727*(1), 012026. https://doi.org/10.1088/1742-6596/2727/1/012026

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, *142*, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Hafizah, N. (2023). Media Pembelajaran Digital Generasi Alpha Era Society 5.0 Pada Kurikulum Merdeka. *Al-Madrasah: Jurnal Pendidikan Madrasah Ibtidaiyah*, *7*(4), 1675. https://doi.org/10.35931/am.v7i4.2699

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Kholiq, A. (2020). Development of B D F-AR 2 (Physics Digital Book Based Augmented Reality) to train students’ scientific literacy on Global Warming Material. *Berkala Ilmiah Pendidikan Fisika*, *8*(1), 50. https://doi.org/10.20527/bipf.v8i1.7881

Koumpouros, Y. (2024). Revealing the true potential and prospects of augmented reality in education. *Smart Learning Environments*, *11*(1), 2. https://doi.org/10.1186/s40561-023-00288-0

Lai, J. W., & Cheong, K. H. (2022). Adoption of Virtual and Augmented Reality for Mathematics Education: A Scoping Review. *IEEE Access*, *10*, 13693–13703. https://doi.org/10.1109/ACCESS.2022.3145991

Mallidis-Malessas, P., Iatraki, G., & Mikropoulos, T. A. (2022). Teaching Physics to Students With Intellectual Disabilities Using Digital Learning Objects. *Journal of Special Education Technology*, *37*(4), 510–522. https://doi.org/10.1177/01626434211054441

Milasari, D., & Setyasto, N. (2023). Effectiveness of the Microsoft Sway Assisted Problem-Based Learning Model on Science Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7028–7035. https://doi.org/10.29303/jppipa.v9i9.4563

Mubarok, I., Nana, N., & Sulistyaningsih, D. (2020). Analisis Penerapan Model Pembelajaran Poe2we Berbasis Hands On Activity Terhadap Kemampuan Berpikir Kritis Siswa. *EduFisika*, *5*(02), 104–111. https://doi.org/10.22437/edufisika.v5i02.10804

Mundir. (2022). *Teknologi Pendidikan: Suatu Pengantar*. Edulitera.

Nafi’ah, Z., & Asih, S. S. (2024). Assemblr Edu Learning Media Based on Augmented Reality to Improve Learning Outcomes of Grade V Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8918–8926. https://doi.org/10.29303/jppipa.v10i11.9544

Nurhidayanti, A., Nofianti, E., Kuswanto, H., Wilujeng, I., & Suyanta, S. (2022). Analisis Kemandirian Belajar Peserta Didik SMP Melalui Implementasi LKPD Discovery Learning Berbantuan Augmented Reality. *Jurnal Pendidikan Sains Indonesia*, *10*(2), 312–328. https://doi.org/10.24815/jpsi.v10i2.23719

Phon, D. N. A. L. E., Rahman, M. H. A., Utama, N. I., Ali, M. B., Halim, N. D. A., & Kasim, S. (2019). The effect of augmented reality on spatial visualization ability of elementary school student. *International Journal on Advanced Science, Engineering and*

Information Technology, *9*(2), 624–629. https://doi.org/10.18517/ijaseit.8.5.4971

Pramesti, D. A. H., Kharisma, A. I., & Irmaningrum, R. N. (2023). Implementasi Kurikulum Merdeka Dalam Pembelajaran IPAS Berbasis Proyek. *Bidayatuna Jurnal Pendidikan Guru Mandrasah Ibtidaiyah*, *6*(2), 98–106. https://doi.org/10.54471/bidayatuna.v6i2.2518

Prananta, A. W., Rohman, A., Agustin, R., & Pranoto, N. W. (2024). Augmented Reality for Interactive, Innovative and Fun Science Learning: Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *10*(SpecialIssue), 45–51. https://doi.org/10.29303/jppipa.v10ispecialissue.7519

Retiyanto, H. F., Putri, S. E., As-Shidiq, M. H., & Suyanta, S. (2023). Systematic Literature Review: Analysis of Student's Critical Thinking Skills towards Chemistry Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 113–121. https://doi.org/10.29303/jppipa.v9iSpecialIssue.6436

Rofi'i, A., Saputra, D. S., Yonanda, D. A., & Febriyanto, B. (2023). Implementasi media pembelajaran augmented reality (AR) dalam meningkatkan kemampuan literasi siswa. *Jurnal Elementaria Edukasia*, *6*(1), 344–350. https://doi.org/10.31949/jee.v6i1.4754.

Ropawandi, D., Husnin, H., & Halim, L. (2023). Comparison of Student Achievement in Electricity Using Augmented Reality between Offline and Online Classes. *Jurnal Pendidikan IPA Indonesia*, *12*(1), 55–66. https://doi.org/10.15294/jpii.v12i1.35403

Sapira, & Ansori, I. (2024). Development of Science Learning Media Based on Augmented Reality Book with Problem Based Learning Model to Improve Learning Outcomes of Third Grade Students. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3249–3260. https://doi.org/10.29303/jppipa.v10i6.7642

Saputra, D. S., Y., A., Susilo, S. V, & Mulyati, T. (2021). *Media Pembelajaran Berbasis Augmented Reality*. Perkumpulan Rumah Cemerlang Indonesia.

Sebastian, R., & Kuswanto, H. (2024). Implementation of Augmented Reality Media in Physics Learning to Develop Students' Cognitive Abilities: A Systematic Literature Review. *International Journal on Studies in Education*, *6*(4), 701–719. https://doi.org/10.46328/ijonse.263

Serevina, V., Sunaryo, Raihanati, & Astra, I. M. (2018). Development of E-Module Based on Problem Based Learning (PBL) on Heat and Temperature to Improve Student's Science Process Skill. *TOJET: The Turkish Online Journal of Educational Technology –*, *17*(3), 26–36. https://eric.ed.gov/?id=EJ1184205

Setiawan, Z., Pustikayasa, I. M., Jayanegara, I. N., Setiawan, I. N. A. F., Putra, I. N. A. S., Yasa, I. W. A. P., & Gunawan, I. G. D. (2023). *Pendidikan Multimedia: Konsep dan Aplikasi pada era revolusi industri 4.0 menuju society 5.0, PT*. Sonpedia Publishing Indonesia.

Siregar, Y. S., Darwis, M., Baroroh, R., & Andriyani, W. (2022). Peningkatan Minat Belajar Peserta Didik dengan Menggunakan Media Pembelajaran yang Menarik pada Masa Pandemi Covid 19 di SD Swasta HKBP 1 Padang Sidempuan. *Jurnal Ilmiah Kampus Mengajar*, *2*(1), 69–75. https://doi.org/10.56972/jikm.v2i1.33

Sugiyono. (2019). *Metode Penelitian Kuantitatif*. Bandung: Alfabeta.

Sujanem, R., Suwindra, I. N. P., & Suswandi, I. (2020). The Effectiveness of Problem-Based Interactive Physics E-Module on High School Students' Critical Thinking. *Journal of Physics: Conference Series*, *1503*(1), 12025. https://doi.org/10.1088/1742-6596/1503/1/012025

Verykokou, S., Boutsi, A.-M., & Ioannidis, C. (2021). Mobile Augmented Reality for Low-End Devices Based on Planar Surface Recognition and Optimized Vertex Data Rendering. *Applied Sciences*, *11*(18), 8750. https://doi.org/10.3390/app11188750

Yastini, Y. N., Nurdian, A. R., & Wikanengsih, W. (2018). Kemampuan Penggunaan Bahasa Baku Mahasiswa Progrm Studi Bahasa Indonesia IKIP Siliwangi di Media Sosial Instagram. *Parole: Jurnal Pendidikan Bahasa Dan Sastra Indonesia*, *1*(5), 659–664. Retrieved from https://journal.ikipsiliwangi.ac.id/index.php/parole/article/view/818

Yilmaz, O. (2021). Augmented Reality in Science Education: An Application in Higher Education. *Shanlax International Journal of Education*, *9*(3), 136–148. https://doi.org/10.34293/education.v9i3.3907

Zahara, S. L., Azkia, Z. U., & Chusni, M. M. (2023). Implementasi Teknologi Artificial Intelligence (AI) dalam Bidang Pendidikan. *Jurnal Penelitian Sains Dan Pendidikan (JPSP)*, *3*(1), 15–20. https://doi.org/10.23971/jpsp.v3i1.4022

Ziden, A. A., Ziden, A. A. A., & Ifedayo, A. E. (2022). Effectiveness of Augmented Reality (AR) on Students' Achievement and Motivation in Learning Science. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(4), 2097. https://doi.org/10.29333/ejmste/11923