



Development of Pascal's Law Learning Media Using Augmented Reality Based on the Marker Based Tracking

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ABSTRACT

The advancement of educational media has continued to evolve in parallel with technological progress. One of the emerging technologies applicable to learning environments is Augmented Reality (AR). The integration of AR in instructional media provides an engaging and interactive learning experience that supports students' comprehension, particularly in understanding complex physics concepts such as Pascal's Law. This study aims to develop an Android-based learning medium utilizing Augmented Reality to facilitate the teaching and learning of Pascal's Law. The research employed a development approach using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Data were analyzed using descriptive analysis techniques. The developed media was evaluated by design experts, content experts, pedagogical experts, and technical experts, as well as tested on 28 students from SMA N 1 Logas Tanah Darat, Kuantan Singingi Regency, Riau Province. The validation results indicated a validity score of 0.903, categorized as very valid, and a practicality score of 90.08, categorized as very practical. These findings suggest that the Augmented Reality based learning media developed for Pascal's Law is both valid and practical for use in classroom learning to enhance students' conceptual understanding.

Keywords: *the ADDIE model, augmented reality, pascal's law, learning media*

INTRODUCTION

The era of globalization has profoundly transformed various aspects of human life, including education. Globalization marked by the cross-border exchange of information, goods, and culture requires education systems to adapt in order to produce human resources (HR) with holistic competencies. As outlined by Roshid and Haider (2024) and Saleem et al. (2024), 21st-century competencies encompass critical thinking, creativity, collaboration, and digital literacy. These competencies are not confined to theoretical knowledge but involve practical applications to address global challenges such as climate change, economic inequality, and rapid technological development.

In the 21st century, the advancement of science and technology (IPTEK) continues to accelerate exponentially (Timothy, 2021). Innovations in artificial intelligence (AI), computing, and biotechnology have reshaped the way humans work, communicate, and solve problems. Consequently, education must evolve by implementing curricula that emphasize active, inquiry-based learning rather than passive memorization. Students must acquire the ability to apply their knowledge to problem-solving, make decisions grounded in scientific reasoning, and integrate technology into daily life competencies that are fundamental to learning physics (Kurniawan, 2024).

Physics education demands systematic and analytical thinking, enabling students to connect theoretical concepts with real-world phenomena (Gündüz, 2024; Murdani, 2020). However, the limited use of technology based learning media often hinders students' conceptual understanding, leading to persistent misconceptions. One particularly challenging topic is fluid statics, which, despite its relevance to everyday life, is often difficult for students to comprehend. Misconceptions frequently arise when students attempt to relate textbook knowledge to observable natural events. Mahmudi and Pramesti (2017) highlighted that mastering fluid statics requires higher-order analytical thinking and reasoning skills.

Individual differences among students further contribute to learning challenges. Some students can grasp abstract physics concepts quickly, while others need more time and concrete representations to fully understand the material (Apriyani et al., 2022). Traditional learning resources, such as textbooks, often fail to provide sufficient visualization or interactivity, making the learning experience less engaging. As a result, students struggle to reason through physics problems effectively (Amalisholeha et al., 2023; Apriani & Sudiansyah, 2024). Therefore, there is a growing need for innovative learning media that can capture students' attention and promote deeper conceptual understanding (Demir, 2024).

Pascal's Law represents a fundamental concept in physics with numerous real-world applications, including hydraulic car lifts and pumps commonly used in automotive systems. However, the inability to directly observe these applications in classroom settings often hinders students' understanding of the principle (Kusrini, 2020). Prior studies have attempted to address this issue using various media. Firmansyah et al. (2024) developed video-based learning media for Pascal's Law, which were found to be suitable but lacked interactivity and real-time feedback between teachers and students. Similarly, research by Rustiana and Rofiqah (2022) utilizing physical visual aids demonstrated good suitability but was limited by high costs and logistical challenges. Considering these limitations, this research aims to develop an interactive, efficient, and easily accessible learning medium that leverages Augmented Reality (AR) technology. The integration of AR in physics learning is expected to create immersive learning experiences aligned with 21st-century education goals, enabling students to visualize abstract concepts such as Pascal's Law more effectively.

One of the most significant technological advancements in education is Augmented Reality (AR), which has been widely utilized to support various aspects of human life (Kalimuthu et al., 2023). AR technology allows the integration of three-dimensional (3D) virtual objects into real world environments, providing new opportunities to simplify complex scientific concepts. In physics learning, AR serves as an innovative tool to help students visualize abstract phenomena that are often difficult to comprehend through traditional, textbook-based approaches (Koumou & Isafiade, 2025; Setiaji & Dinata, 2020). By projecting 3D animated representations of physical concepts into the real world, AR enhances students' conceptual understanding and engagement (Waskito et al., 2024).

In addition to improving conceptual clarity, AR technology offers practical advantages in terms of efficiency and accessibility. It enables learners to interact with educational content through smartphones by simply activating an application and scanning specific markers using the device's camera. A marker is a specially designed image pattern that can be recognized by the AR system, allowing a virtual 3D object to appear once detected. Generally, AR markers are divided into two types: marker-based tracking and markerless tracking. Marker based tracking relies on predefined images or symbols that guide the system in determining the position and orientation of the virtual object, thus constructing an accurate 3D visualization (Wahyudi et al., 2019). To function effectively, image markers must possess certain characteristics, including adequate contrast, clarity, complexity, and the absence of overlapping features.

In this study, the marker based tracking approach was employed using image markers themed around Pascal's Law, such as hydraulic car systems. When users point their smartphone

camera at these markers, the application displays interactive 3D animations illustrating the principles of Pascal's Law in real time (Wahyudi et al., 2019). This feature allows students to observe the working mechanism of hydraulic systems directly through their mobile devices, making the learning process more engaging and flexible, as it can be accessed anytime and anywhere.

The development process of the AR-based learning application followed the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Sugiyono, 2017). This model was chosen because it provides a systematic framework that ensures the developed product aligns with learners' needs and educational objectives. Through the development of a Pascal's Law learning medium using Augmented Reality with marker-based tracking, this study aims to enhance students' conceptual understanding and interest in physics, particularly in learning about fluid mechanics.

METHODOLOGY

This study employs the Research and Development (R&D) approach, which is designed to produce educational products that meet specific learning needs (Yulia et al., 2023). The R&D method was chosen because it emphasizes systematic stages of analysis, design, testing, and evaluation to ensure the final product is both effective and relevant to users. One of the key strengths of this approach lies in its initial needs analysis phase, which helps identify user requirements prior to product development. To guide the development process, this research adopts the ADDIE instructional design model, a structured framework widely used in educational media development. The ADDIE model is preferred because it incorporates evaluation and revision at each stage, ensuring that the resulting product is valid, practical, and aligned with learner expectations. Moreover, this model allows the development of learning media adaptable to both offline and online learning environments.

The ADDIE model consists of five sequential stages: Analysis, Design, Development, Implementation, and Evaluation (Pratiwi & Rahmad, 2024). Analysis involves identifying problems, defining learning objectives, and assessing user needs. Design focuses on creating learning scenarios, interface layouts, and technical specifications for the AR-based application. Development refers to the actual production of the learning media, integrating Augmented Reality features and markers related to Pascal's Law. Implementation includes testing the product with students and experts to evaluate usability and functionality. Evaluation encompasses both formative and summative assessments to refine the product based on feedback and ensure its overall effectiveness.

An illustration of the ADDIE model applied in this study is presented in Figure 1.

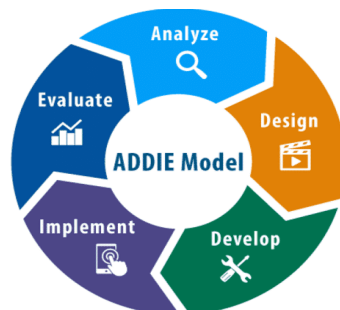


Figure 1. ADDIE Models

This research was carried out up to the development stage, focusing on validity and practicality testing of the developed learning media. The validity test was conducted through expert evaluations, which included assessments from material experts, media experts, and pedagogical experts, following the procedures adapted from Nisrina et al. (2022). Meanwhile, the practicality

test was administered using a total sampling technique, involving three physics teachers and 28 students from Grade XI-1 as respondents. The data obtained from both expert evaluations and user responses were analyzed to determine the levels of validity and practicality. The percentage scores from these evaluations were calculated using Equation (1), as presented below:

$$\text{Validity}(V) = \frac{\text{total score obtained}}{\text{total score}} \quad (1)$$

Next, the validation score results are categorized into table 1 as follow:

Tabel 1. Validation Result Categories

No	Average Score Interval	Criteria
1	$0.80 < V \leq 1.00$	Very High
2	$0.60 < V \leq 0.80$	High
3	$0.40 < V \leq 0.60$	Fair
4	$0.20 < V \leq 0.40$	Low
5	$0.00 < V \leq 0.20$	Very Low

Source: (Azwar, 2015)

Based on the assessment criteria, the developed product is considered feasible or valid if all indicators in the validity instrument yield a validity coefficient (V) greater than 0.4. Conversely, if the coefficient value $V < 0.4$, the product is categorized as invalid or unfit for use (Fernando & Sarkity, 2023). Furthermore, the practicality test was analyzed to determine the extent to which the developed learning media could be effectively utilized by teachers and students. The level of practicality was calculated using Equation (2), as presented below.

$$\text{Practicality (P)} = \frac{\text{total score obtained}}{\text{total score}} \times 100 \quad (2)$$

The practicality score results are categorized into table 2 as follow:

Table 2. Practicality Result Categories

No	Practicality Value	Criteria
1	$80 < P \leq 100$	Very Practical
2	$60 < P \leq 80$	Practical
3	$40 < P \leq 60$	Quite Practical
4	$20 < P \leq 40$	Loss Practical
5	$P \leq 20$	Not Practical

Source: (Riduwan, 2011)

Based on the assessment criteria, a product is considered practical and suitable for large-scale implementation if all indicators in the practicality instrument yield a practicality coefficient (P) greater than 40. Conversely, if the P value is less than 40, the product is categorized as impractical, indicating that further improvements or revisions are required in the corresponding assessment aspects before broader application can be conducted.

RESULT AND DISCUSSION

This research and development have led to the creation of a Pascal's Law learning application utilizing Augmented Reality technology for high school students. The development procedure used is the ADDIE model which consists of five stages and in this study only carried out up to the development stage, namely:

Analysis

Physics subjects in high school include several topics that have proven difficult to understand only through textbooks or traditional teaching methods. As a Physics teacher, the researcher chose Pascal's Law as the focus for the even semester of grade 11 at SMA N 1 Logas Tanah Darat, Kuantan Singingi Regency, Riau Province. Basically, Pascal's Law is part of various laws of Physics that are very useful for everyday human life. However, understanding Pascal's Law has proven difficult if only relying on textbook-based learning, this is in line with research conducted by previous studies which states that 88% of students experience difficulties in working on problems on Pascal's law material. where this difficulty is caused by students' difficulty in understanding the concept and the media used by teachers in delivering the material is less appropriate (Maisyaroh et al., 2022; Zulfa et al., 2018).

Design

After identifying and analyzing the problem in the analysis stage, the next stage is designing learning media in the form of augmented reality. This includes developing learning tools, designing the development of physics e-learning, and developing research instruments as illustrated in Figure 3.

The development process includes several stages, namely developing learning tools, developing e-learning design, and developing research instruments. The learning tools developed are teaching modules that are appropriate for the learning media being developed. In developing the e-learning design, the media design process consists of two steps: designing a history board and a storyboard. The history board includes the opening page, login page, content, and closing page, while the storyboard consists of scenes, displays, and descriptions. Scenes describe the creation of augmented reality, displays contain images of the e-learning displays for each section, and descriptions provide explanations of the images displayed in the displays. Furthermore, the development of research instruments involves the use of a validity assessment sheet and a practicality assessment sheet for teachers and students. The design stage is crucial for creating the conceptual blueprint of the application, as it represents the phase in which the conceptual form takes shape before the actual design is crafted in the subsequent phase. The success of the following stages is interconnected with this phase; thus, the product must be intricately designed in the design stage.

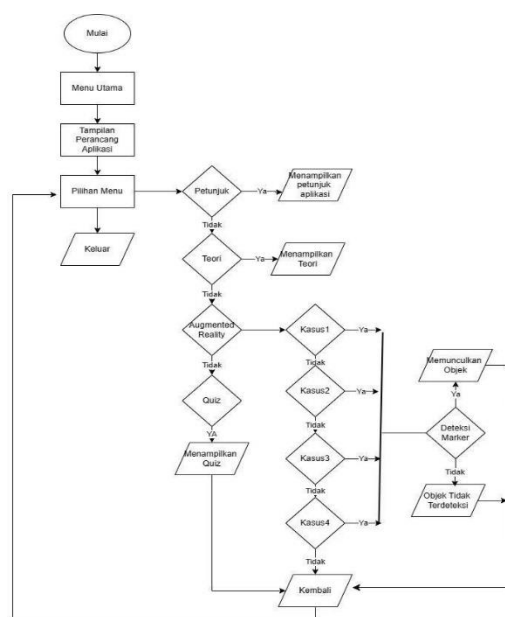


Figure 3. Design Stages

Augmented Reality is a technology capable of projecting 2D or 3D objects into the real world. Therefore, users can view 3D objects with the aid of an application. These 2D or 3D objects appear when the application successfully scans a marker stored in the Vuforia database. The successful display of 2D or 3D objects depends on the light conditions and the distance during the scanning process.

Development

The development phase represents the implementation stage of the ADDIE model, during which the conceptual product designs formulated in the previous stages are transformed into a functional and usable learning application. In this phase, all components that were initially presented as conceptual frameworks are systematically realized into an operational product. Furthermore, this stage involves the process of rendering virtual objects into the real world environment, allowing users to visualize 3D models through Augmented Reality technology. The procedural steps for rendering these virtual objects into real-world contexts are illustrated in Figure 4.

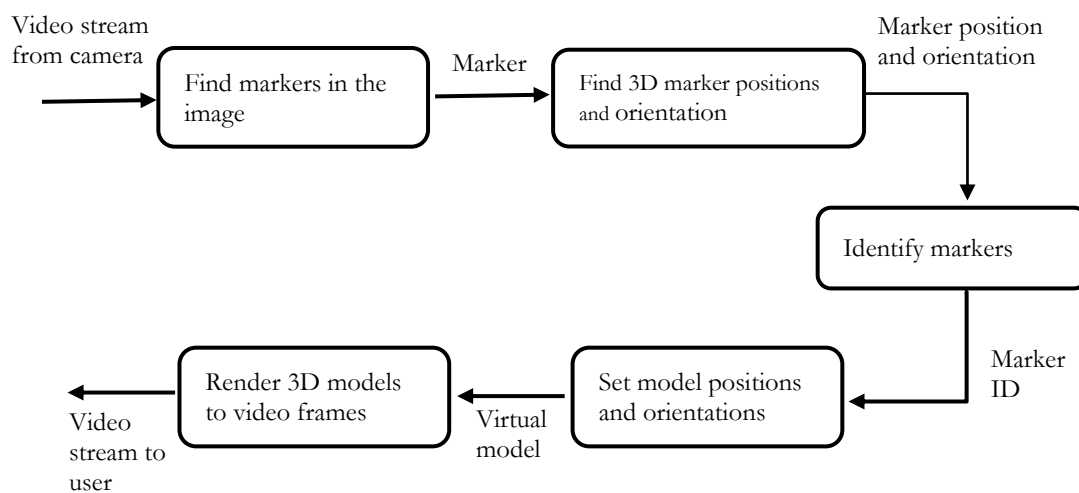


Figure 4. Development is the ADDIE model

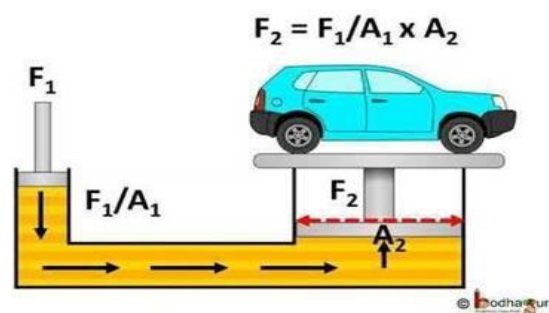


Figure 5. Maker Augmented Reality in This Development

Here is the display of the Augmented Reality Pascal's Law application that has been developed

Main Interface



Figure 6. Main Interface

Application Designer Interface



Figure 7. Application Designer Interface

The Application Designer Interface is a display that showcases information about the application designer, consisting of the designer's name and ID number.

Menu Selection Display

The main interface represents the initial display encountered by users upon launching the Augmented Reality-based Pascal's Law learning application. This interface serves as the entry point to the application, providing users with access to its primary features and navigation options. The visual layout of the main interface is presented in Figure 8.



Figure 8. Menu Selection Display

The menu selection interface provides users with several navigation options designed to facilitate independent learning. These include four primary buttons: Guidance, which directs users to the instructional section; Theory, which provides access to the conceptual content of Pascal's Law; Quiz, which leads to the assessment section; and Augmented Reality, which enables users to visualize virtual objects through AR-based object detection. Within the Augmented Reality section, four distinct simulation scenarios are available, each illustrating the mechanism of a car jack operating under Pascal's Law principles. The key distinction among these scenarios lies in the

variation of the car jack's motion and the manner in which it lifts the load, allowing students to observe the physical implications of pressure distribution in real-world applications.

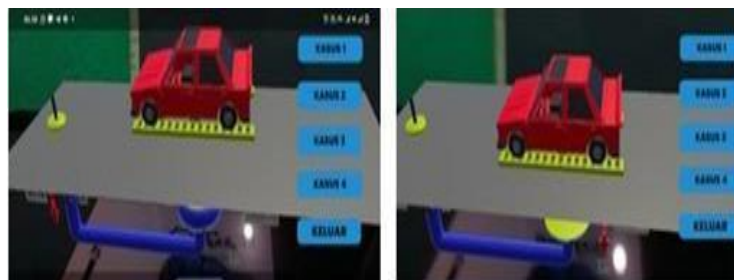


Figure 9. Augmented Reality Display Developed

Instruction Display

In the menu selection display, there are buttons for guidance, leading to the instruction display, theory directing to the theory section, quiz directing to the quiz display, and Augmented Reality directing to object detection in Augmented Reality. Users can choose from 4 scenarios to detect Augmented Reality objects. The difference in each scenario lies in the depiction of the car jack lifting the load.

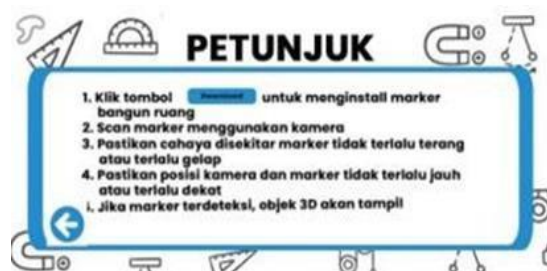


Figure 10. Instruction Display

After the augmented reality development was carried out, the validity test and practicality test were carried out. The results of the validity test and practicality test carried out are as follows:

Validity test

The validity test of the developed Pascal's Law learning media was carried out by three expert validators using an evaluation instrument that encompassed pedagogical, material, and media aspects, comprising a total of 38 items. All validators were lecturers from the Postgraduate Program in Physics Education, University of Riau, who possessed relevant expertise in instructional media and physics education. The validation process was conducted in two stages. In the first stage, the experts evaluated the pedagogical and media aspects twice and the material aspect once, referring to the criteria outlined in the validation sheet. The results of the initial evaluation indicated that two validators identified several indicators across different aspects that did not yet meet the feasibility criteria, while one validator categorized all aspects as feasible. Based on these findings, the researcher revised the product in accordance with the experts' feedback and recommendations to enhance its quality and alignment with pedagogical standards. The final validation results, after revision, demonstrated a significant improvement in all aspects, as presented in Table 3.

Table 3. Expert Validation Results

Name	The Total Number of Validity Scores Given
Expert 1	130
Expert 2	142
Expert 3	129
Amount	401

Based on Table 3, the total validity score obtained was 401, which, when converted using Equation 1, yields a validation index of 0.903. According to the classification presented in Table 1, this value falls within the “very valid” category. Thus, it can be concluded that the Augmented Reality-based learning media developed in this study is highly valid and feasible for implementation in classroom learning. These findings are consistent with the results reported by Meilana (2017), Adi & Putri (2025), and Ali et al. (2021), which demonstrated that the development of Augmented Reality (AR) learning media in physics education generally attains a high level of validity in terms of both content and pedagogical design. The integration of 3D interactive simulations within AR environments enhances students’ conceptual understanding by transforming abstract physics principles into more tangible and visual representations. Moreover, previous research emphasizes that AR-based media can increase students’ motivation, facilitate independent exploration, and provide real-time feedback, thereby minimizing misconceptions and user errors during learning activities. In line with these findings, the developed learning media in this study is considered appropriate and effective for use in supporting students’ comprehension of Pascal’s Law in physics instruction..

Practicality test

The practicality test was conducted to evaluate the feasibility and usability of the Pascal’s Law learning media developed using Augmented Reality technology in physics instruction. The purpose of this test was to determine the extent to which the learning media could be effectively implemented in classroom learning environments. The practicality assessment was carried out by physics teachers and students using two different instruments. The teacher practicality assessment sheet consisted of indicators related to ease of use, effectiveness, and usefulness of the media, while the student response sheet measured aspects of ease of use and usability. The practicality instrument used in this study comprised a total of 16 items. The results of the practicality evaluation as obtained from student responses are presented in Table 4.

Table 4. Student Practical Results

Name	The Total Number of Practicality Scores Given
Student 1	62
Student 2	76
Student 3	76
Student 4	58
Student 5	66
Student 6	67
Student 7	61
Student 8	76
Student 9	66
Student 10	72
Student 11	76
Student 12	76
Student 13	64

Name	The Total Number of Practicality Scores Given
Student 14	61
Student 15	66
Student 16	76
Student 17	76
Student 18	76
Student 19	76
Student 20	68
Student 21	76
Student 22	76
Student 23	65
Student 24	61
Student 25	56
Student 26	76
Student 27	54
Student 28	58
Amount	1917

Based on Table 4, the total practicality score obtained was 1,917, which, when calculated using Equation 2, resulted in a practicality index of 90.08. Referring to the classification in Table 2, this score falls within the “very practical” category. Therefore, it can be concluded that the Augmented Reality-based learning media developed in this study is highly practical and suitable for use in classroom learning activities. These findings are consistent with the results reported by Abdullah (2016), Meilana (2017), and Ali et al. (2021), who found that the development of Augmented Reality (AR) learning media for Pascal’s Law consistently falls into the very practical category. The practicality of AR-based media stems from its ability to simulate fluid pressure experiments interactively, allowing students to visualize and manipulate physical phenomena without the need for expensive laboratory equipment.

Moreover, the results of this study indicate that the developed AR media enhances learning efficiency and ease of use, as reflected in the high practicality scores obtained from both teachers and students. The use of AR technology reduces experiment preparation time and minimizes potential safety risks, while still promoting active learning through direct visualization such as observing how pressure varies within a closed container. Consequently, students can gain a deeper conceptual understanding of fluid mechanics in a more engaging and accessible way. This research successfully produced an Augmented Reality-based learning medium focusing on Pascal’s Law, designed to improve students’ conceptual understanding and learning interest, in alignment with 21st-century learning competencies emphasizing technology integration. Following the development phase, the product underwent a feasibility validation by media, material, and pedagogical experts, resulting in a validity index of 0.903, classified as very valid.

The subsequent practicality test involving teachers and students yielded a practicality index of 90.08, categorized as very practical. These findings affirm that the developed AR-based learning media is both feasible and effective for use in physics education. Furthermore, this learning application can be utilized not only during guided instruction but also independently, serving as a self-reflective learning tool for students to review previously studied material. The inclusion of 3D animations and descriptive explanations enables students to explore abstract concepts more intuitively and supports collaborative learning through discussions with peers and teachers.

CONCLUSION

Based on the findings of this study, the Augmented Reality-based learning media developed for Pascal's Law demonstrated a high level of validity, with a validity index of 0.903, and a practicality score of 90.08, categorized as very practical. These results indicate that the developed media meets both content and pedagogical standards, and is therefore feasible for implementation in physics learning. The integration of Augmented Reality technology allows students to visualize fluid pressure phenomena in an interactive and engaging manner, thereby enhancing conceptual understanding and supporting active learning aligned with 21st-century educational competencies. This study confirms that Augmented Reality serves as an effective learning tool that bridges the gap between abstract theory and real-world application. By utilizing mobile-based AR technology, students can conduct virtual experiments anytime and anywhere, reducing dependency on conventional laboratory setups and promoting independent learning. However, the implementation of this technology also presents several limitations, including the requirement for stable internet access and devices equipped with high-quality cameras to ensure optimal performance. Furthermore, this development was limited to Pascal's Law within the subtopic of fluid mechanics. Therefore, future research is encouraged to expand the scope of AR-based learning media to include other topics within fluid dynamics and broader areas of physics. Enhancing interactivity, accessibility, and content variety will further strengthen the role of AR as a transformative tool in science education.

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