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Development of STEM-Based Virtual Reality to Enhance High School Students' Conceptual Understanding

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Abstract. The understanding of concepts among students is still relatively low due to the suboptimal use of learning media, making it difficult for students to grasp the material, especially abstract physics concepts. This research aims to develop STEM-based virtual reality media, as well as to determine its feasibility, user response, and effectiveness in improving high school students' conceptual understanding. The method used is research and development with the ADDIE model (analysis, design, development, implementation, evaluation), with the research subjects being 10th-grade students at SMAN 1 and SMAN 10 Bandar Lampung. The instruments used included validation sheets for media experts, materials, and test items; responses from students and educators; as well as concept understanding tests through pretests and posttests. The research results show that the developed media is deemed suitable based on the validator's assessment, with responses from educators and students indicating a very interesting category. The N-gain score with an average of g=0.55 indicates a moderate increase in students' conceptual understanding, making this media suitable and effective for use in learning.

Keywords: virtual reality, STEM, conceptual understanding

1. Introduction

Education is one of the most important parts of a country's growth. A country can produce a generation with strong character and quality that is capable of competing in the global era by providing good education [1]. It cannot be denied that technological development in the field of education continues to advance. Almost all generations, especially Generation Z, are accustomed to using various forms of technology in their daily lives, including in the learning process. This condition presents both a great opportunity and a challenge for educators to adjust their teaching strategies to the characteristics and needs of students in their era [2].

Educators have a strategic role in improving the quality of the learning process, not only as information transmitters but also as designers of meaningful learning experiences. To support the achievement of systematic learning objectives, educators are required to design learning systematically, starting with preparing teaching materials, selecting appropriate models and methods of instruction, and determining relevant and innovative learning media. With proper planning based on the needs of the learners, the learning process can become more effective, interactive, and in line with technological advancements and the demands of the 21st century [3].

In the 21st century, technology has become an inseparable part of the world of education. Through technology, students can explore various learning resources from around the world, interact with materials in a more engaging way, and learn in a manner that suits their needs. 21st-century education demands learners possess a set of 21st-century skills known as the 4Cs, which are critical thinking, creativity, collaboration, and communication. These skills become an important asset for the younger generation to adapt to the dynamics of globalization, technological advancements, and the challenges of the Industrial Revolution 4.0 and Society 5.0 [4]. Critical thinking skills are important for students in understanding and solving problems in their daily lives. This ability is closely related to conceptual

understanding; students cannot analyze or evaluate well if the basic concepts are not properly understood. Conversely, when students have a strong conceptual understanding, their critical thinking skills develop more optimally. Thus, the enhancement of conceptual understanding and the strengthening of critical thinking are two complementary competencies in modern science education.

One of the approaches that is highly relevant to current technological developments is STEM-based learning (Science, Technology, Engineering, and Mathematics) [5]. This approach combines four fields of study to build 21st-century skills such as critical, creative, and innovative thinking; problem-solving and decision-making abilities; as well as the ability to communicate and collaborate within a group [6]. By utilizing technology as part of the STEM learning process, students not only learn theory but also can observe, analyze, and solve real-world problems contextually. Integrating technology with STEM creates more active, meaningful, and real-world-relevant learning experiences [7]. Various technological innovations have been integrated into learning activities, one of which is the use of virtual reality.

Virtual reality is an immersive technology that allows users to interact with a three-dimensional environment realistically. In the context of education, virtual reality serves as an innovative learning medium capable of simulating abstract scientific concepts, enhancing experiment-based learning experiences, and increasing student engagement. Virtual reality technology is highly potential in helping students understand difficult concepts that are not easily observed directly in the real world.

Conceptual understanding is a fundamental aspect of learning, especially in science subjects. Students who have a good understanding of concepts are able to connect prior knowledge with new material, explain a phenomenon correctly, and apply concepts in different situations [8]. However, various studies show that many students struggle to understand abstract concepts because the teaching methods are still teacher-centered and lack visualization or object manipulation. Therefore, innovative learning media such as virtual reality are needed to help students build clearer and stronger mental representations of a concept.

Based on the results of the preliminary research conducted in three schools, it was found that the level of conceptual understanding among students generally has not shown optimal results. This condition indicates the need for the application of innovative learning media oriented toward the development of higher-order thinking skills. One alternative that can be implemented is the development of virtual reality-based learning media with a STEM approach, as this media can provide an interactive and contextual learning experience, thereby stimulating students to think critically in understanding physics concepts, particularly on the topic of work and energy [9].

The integration of the STEM approach with virtual reality technology further enhances the effectiveness of learning. STEM-based learning encourages students to think critically, collaborate, and solve problems through the application of cross-disciplinary concepts. In addition, this approach also trains technology literacy, reading, writing, observation, and the application of science in real-life contexts. By bringing real-world sensations into a virtual environment, virtual reality is able to enhance students' learning retention and conceptual understanding.

Several previous studies have shown that the STEM approach and the use of virtual reality positively contribute to the improvement of learners' conceptual understanding. Research by Mawarni et al. demonstrated that STEM-based outbound activities can enhance students' understanding of physics concepts and their learning motivation Furthermore [10]. research by Nurjanah et al. found that immersive VR simulations can help students understand abstract measurement concepts through concrete visualization [11]. Another study by Aminudin et al. showed that VR generally has a positive impact on motivation and concept understanding based on a review of various studies [12]. S Meanwhile, Pramasela et al. proved that VR is effective in improving science concept understanding in early childhood [13].

Although various studies have yielded positive results, most still focus on the use of virtual reality or STEM separately. Until now, there has not been much research specifically combining both in the form of STEM-based virtual reality learning media to enhance high school students' conceptual understanding. Therefore, this research aims to develop STEM-based virtual reality media, as well as to determine its feasibility, user response, and effectiveness in improving high school students' conceptual understanding.

2. Method

This research was conducted at SMAN 1 Bandar Lampung and SMAN 10 Bandar Lampung in the even semester of the 2025/2026 academic year with class X research subjects. The type of research applied in this study is research and development, which aims to produce a product and measure the effectiveness of the product in its context of use [14]. The development design refers to the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation [15].

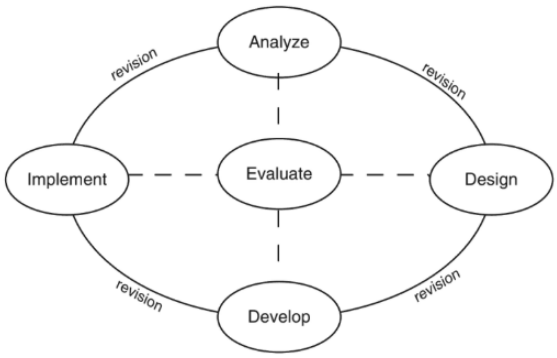

Figure 1. ADDIE development design [16].

This model was chosen because its steps are simple and structured systematically according to the research design. In addition, the ADDIE model is flexible because the evaluation process is carried out at each stage. Thus, revisions can be made if deficiencies are found at each stage. The stages in the development of ADDIE are shown in Figure 2.

The developed VR media focuses on sub-concepts of work and energy materials such as work, kinetic energy, potential energy, and the law of conservation of energy. The presentation of concepts in the media is done thru a scene-based virtual environment equipped with narration, simple interactions, and animated video presentations for each part of the material. This is adjusted to the limitations of the VR platform used, where objects cannot fully move dynamically except in the form of animations or videos. Therefore, the visualization of physics concepts is displayed thru a combination of virtual environments and educational videos to help learners understand the process of energy transformation more concretely.

The research instruments used include validation sheets from subject matter experts, media experts, and learning instrument experts, questionnaires for student and educator responses, as well as concept understanding tests in the form of three-tier multiple-choice questions. The test is formed by a pretest and posttest to determine the improvement in students' conceptual understanding.

The data analysis technique used is quantitative descriptive analysis. The validation results and response questionnaires are analyzed using feasibility percentages [18].

Table 1. Criteria interpretation.

No.	Interval	Criteria
1.	$80\% < score \leq 100\%$	Very Eligible
2.	$60\% < score \leq 80\%$	Eligible
3.	$40\% < score \leq 60\%$	Moderately Eligible
4.	$20\% < score \leq 40\%$	Less Eligible
5.	$0\% < score \leq 20\%$	Not Eligible

With the presence of the criteria interpretation scale table, researchers can determine the level of interest in Virtual Reality media as a learning medium based on the percentage of the obtained assessment. Meanwhile, the improvement in conceptual understanding is analyzed using the N-gain value calculated with the formula [19]:

$$N - gain = \frac{(Skor\ posttest - Skor\ pretest)}{(Skor\ maksimum - Skor\ pretest)}. \quad (1)$$

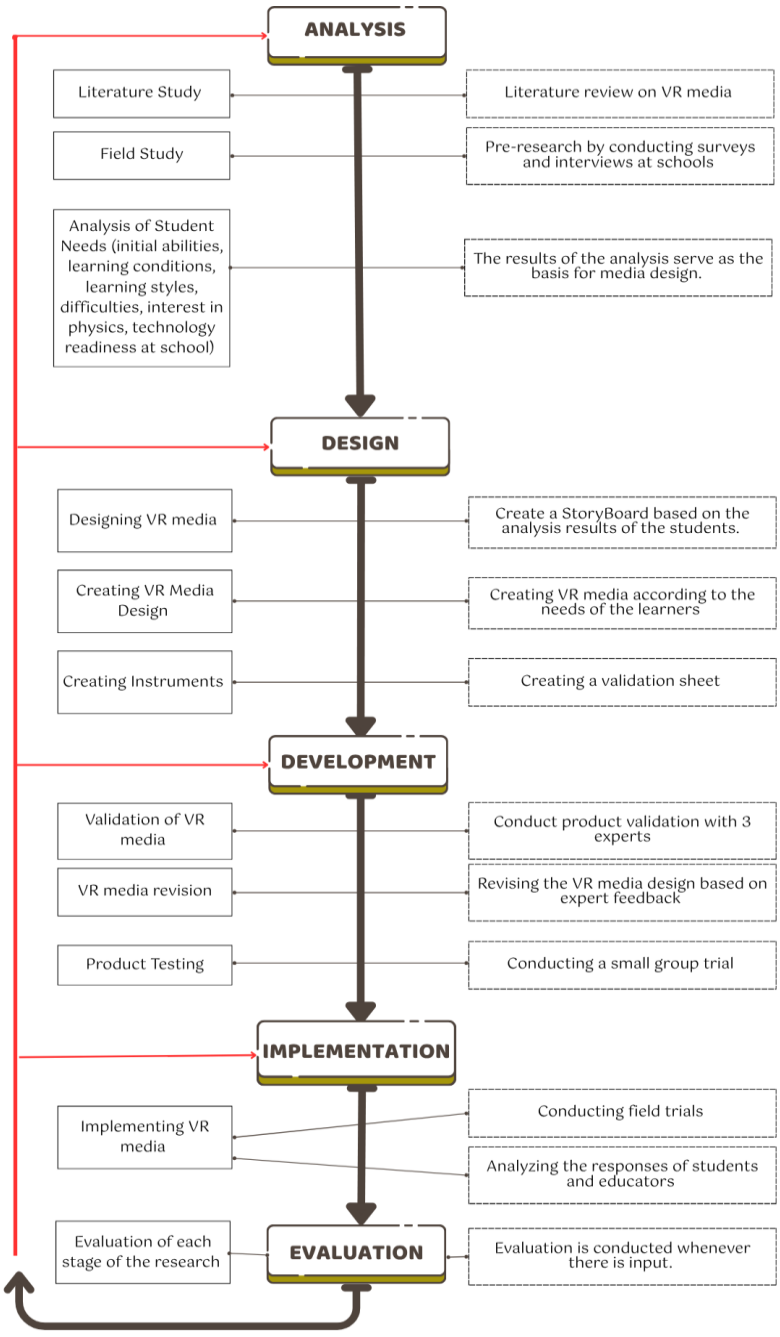

Figure 2. Development research flow [17].

The N-gain value is then categorized into three levels: high, medium, and low.

Table 2. N-gain score categories [20].

N-gain Score	Category
$g > 0.7$	High
$0.3 \leq g \geq 0.7$	Medium
$g < 0.3$	Low

The results of the analysis are used to determine the feasibility and effectiveness of the developed STEM-based Virtual Reality media.

3. Results and Discussion

3.1. *Result*

The developed product is a STEM-based Virtual Reality media designed and developed using the MilleaLab Creator platform with the aim of enhancing students' conceptual understanding. The integrated material is the topic of Work and Energy for 10th-grade high school students. This process begins thru five stages: analysis, design, development, implementation, and evaluation.

3.1.1. *Analysis.* Stage At this stage, data collection is conducted to support the development of media that meets the needs of students and can enhance their conceptual understanding. Data is obtained thru the distribution of questionnaires to students and interviews with educators at SMAN 1 and SMAN 10 Bandar Lampung. The analysis results show that students' conceptual understanding is not optimal and their interest in learning is still low, especially in solving problems and applying formulas. Additionally, the use of learning media such as PowerPoint and textbooks is considered insufficient in helping students understand the material optimally, leading to the development of more engaging and relevant Virtual Reality media.

3.1.2. *Design.* The design stage is conducted to create a scheme and design the development of Virtual Reality based on the analysis that has been carried out previously. The developed product is a STEM-based Virtual Reality aimed at enhancing high school students' understanding of concepts. In this stage, media design is carried out by determining learning content in 3D form using MilleaLab Creator, creating designs and storyboards to illustrate the appearance, user interaction, and the sequence of material presentation, as well as preparing research instruments in the form of validation sheets, concept understanding tests, and response questionnaires for students and educators to assess the feasibility and effectiveness of the developed media.

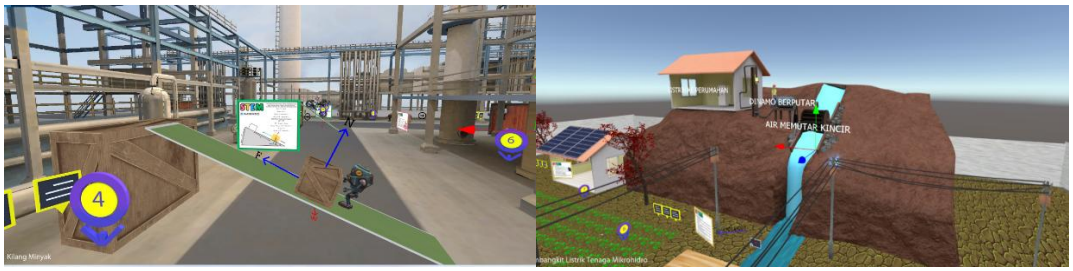

Figure 3. Display design in Millealab creator.

Figure 4. Millealab viewers menu display.

Table 3 presents the integration of the STEM approach into the developed Virtual Reality media.

Table 3. Integration of STEM in virtual reality.

STEM Aspect	Description
Science	Integration of STEM in Virtual Reality STEM Aspect Description Science Shown thru the understanding of the concepts of work, energy transformation, and the law of conservation of energy observed by students in each scene.
Technology	Technology Use of real technology examples such as hydroelectric power plant turbines, solar panels, and windmills as energy conversion tools.
Engineering	Is played thru explanations of how energy generation systems work, from natural energy sources that spin turbines or blades to generators producing electrical energy and distributing it to the community.
Mathematics	The relationship between the concepts of work, force, displacement, and energy changes is understood conceptually.

3.1.3. *Development.* Stage At this stage, the development of STEM-based virtual reality media is carried out according to the design that has been prepared in the design stage. Next, the developed media are validated by experts, including 2 lecturers who specialize in subject matter, 2 lecturers who specialize in media, and 2 lecturers who specialize in learning instruments, to assess the product's feasibility before implementation. The average results of the validation assessment from the experts are presented in Table 4.

Table 4. Expert validation results on content.

No.	Assessment Aspect	Skor (%)	Category
1.	Content Feasibility	88.6%	Very Feasible
2.	Language Use	92.0%	Very Feasible
3.	Presentation Aspects	86.7%	Very Feasible
4.	STEM Approach	90.0%	Very Feasible
	Average	89.3%	Very Feasible

Based on the results of the material expert validation in Table 4, all assessment aspects received a 'very feasible' category with an average score of 89.3%, indicating that the presented material is in accordance with the developed media in terms of content, language, and presentation aspects and has been integrated with the STEM approach.

Table 5. Media expert validation results.

No	Assessment Aspect	Skor (%)	Category
1.	Visual Appearance	85.0%	Very Feasible
2.	Font Usage	86.7%	Very Feasible
3.	Audio Feasibility	83.3%	Very Feasible
4.	User Friendliness	85.0%	Very Feasible
	Average	85.0%	Very Feasible

In Table 5, the visual appearance aspect received a score of 85.0% with a very feasible category, indicating that the media's visual design is attractive and suitable for use in learning. The font usage aspect received a score of 86.7% with a very feasible category, meaning that the type and size of the font used are easy to read by the learners. Additionally, the user-friendliness aspect received a score of 85.0% in a very feasible category, indicating that the media is easy to operate for the learners. Overall, the average score obtained was 85.0% with a very feasible category; thus, the developed virtual reality media is deemed suitable for use in learning.

The results of the validation of the concept understanding items, which consist of 14 three-tier multiple-choice questions, obtained an average score of 91.7% with a very feasible category. This indicates that the test instrument is valid and can be used to measure students' conceptual understanding of the material on work and energy.

Table 6. Results of item validation.

No	Assessment Aspect	Skor (%)	Category
1	Content of the Questions	97.5%	Very Feasible
2	Question Construction	91.6%	Very Feasible
3	Language of the Questions	86.0%	Very Feasible
	Average	91.7%	Very Feasible

3.1.4. *Implementation.* At this stage, field trials were conducted with 10th-grade students at SMAN 1 and SMAN 10 Bandar Lampung. During the trial process, educators and students used Virtual Reality media in learning activities, then filled out response questionnaires prepared to assess aspects of ease of use, appearance, and the benefits of the media in enhancing conceptual understanding.

Table 7. Results of student and educator responses.

No	Responden	Assessment Aspect	Skor (%)	Category
1.	Student	Content Aspect	86.5%	Very Interesting
		Media Aspect	86.3%	Very Interesting
		Concept Understanding Aspect	88.0%	Very Interesting
		Average	87.2%	Very Interesting
2.	Educators	Content Aspect	91.7%	Very Interesting
		Media Aspect	95.7%	Very Interesting
		Usefulness Aspect	98.6%	Very Interesting
		Average	95.3%	Very Interesting

Based on Table 7, the responses from the students show an average score of 87.2% with a very interesting category, with the highest score in the concept-understanding aspect at 88.0%. This indicates that the developed media can help improve students' concept understanding. Meanwhile, the educators' responses obtained an average of 95.3% with a very interesting category, with the highest score in the usefulness aspect. This indicates that educators consider the developed virtual reality media to be very beneficial in learning. Overall, the Virtual Reality media received very positive responses from both students and educators.

In addition to response questionnaires to the media, test instruments are also used to measure students' conceptual understanding. The measurement is conducted thru the administration of pretests and posttests to determine the improvement in conceptual understanding after the use of learning media.

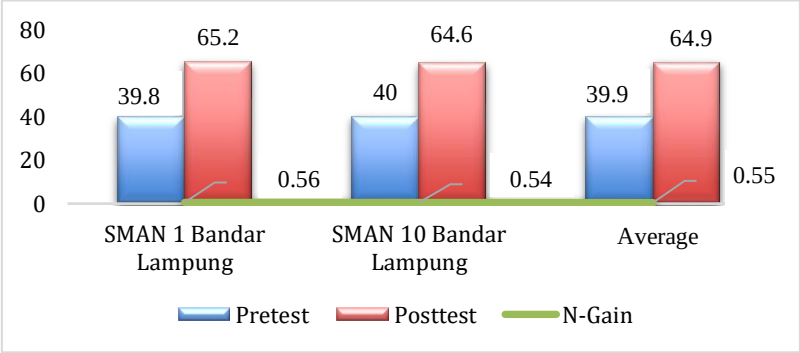

Figure 5. Data on the improvement of N-gain concept understanding.

From Figure 5, the N-gain values at both schools show an increase in the moderate category, namely 0.56 at SMAN 1 Bandar Lampung and 0.54 at SMAN 10 Bandar Lampung,

with an average of 0.55. This indicates that students' conceptual understanding improved after the use of Virtual Reality media.

3.1.5. *Evaluation.* Evaluation is conducted at every stage to ensure the quality of the developed product improves, from the analysis stage to implementation. Input from experts, students, and educators is used as a basis to improve the VR media, ensuring that it meets the diverse needs and preferences of high school students. This continuous evaluation process results in a final product that is feasible, effective, and capable of providing a meaningful learning experience for high school students.

3.2. *Discussion*

The validation results indicate that the STEM-based virtual reality media developed falls into the category of being suitable for use in learning. Appropriate media is one of the important factors in supporting an effective learning process [21]. This feasibility indicates that the media has met the criteria of content, appearance, and usefulness as a learning medium. The feasibility assessment is conducted using a Likert scale, which is then converted into a percentage to determine the quality category of the media. The score conversion process aims to systematically determine the feasibility level of each assessed aspect [22].

Theoretically, suitable learning media should be able to help students understand the material more easily and engagingly. Technology-based media such as virtual reality can present visualisations of abstract concepts, thereby enhancing the quality of learning. This is in line with the opinion that the use of appropriate learning media can enhance learning outcomes and the effectiveness of student learning [23].

Apart from that, the integration of the STEM approach in Virtual Reality media adds value because STEM-based learning encourages students to connect concepts across disciplines and solve problems contextually [24]. This approach can enhance students' critical thinking skills and conceptual understanding, particularly by providing immersive experiences that allow them to apply theoretical knowledge in practical scenarios.

The survey results indicate that the responses of students and educators toward STEM-based virtual reality media fall into the intriguing category. This positive response indicates that the media is capable of increasing students' interest and engagement in the learning process [25][26][27]. The positive response from students shows that the use of virtual reality provides a different learning experience compared to conventional learning. Virtual reality media allow students to interact directly with learning objects, making the learning process more active and meaningful. This is in line with the theory that experiential learning can enhance student engagement and facilitate concept understanding [28].

Moreover, the very positive response from educators indicates that STEM-based virtual reality media can help teachers deliver material more effectively. Teachers consider this media beneficial because it can visualize abstract concepts that are difficult to explain through lectures alone. This is in line with the opinion that interactive digital media such as VR can enhance learning motivation and facilitate the delivery of material by educators [29].

Educators implement virtual reality media in learning through the introductory, core, and closing stages. In the introductory stage, educators provide an apperception related to the concepts of work and energy. In the core stage, students explore the material through a scene-based virtual environment equipped with tutor narration and animated videos to observe the concepts of work and energy. Subsequently, students engage in discussions and answer concept-based questions. In the closing stage, reflection and conclusion drawing are conducted.

The effectiveness of STEM-based virtual reality media in enhancing students' conceptual understanding was analyzed using the N-gain test. This test is used to determine the improvement in conceptual understanding based on the pretest and posttest results given before and after the learning process. The analysis results show that the N-gain value falls into the moderate category, which means there is an improvement in conceptual understanding after using STEM-based virtual reality media. This category indicates that the developed media is effective in helping students understand physics concepts.

The determination of the N-gain category is based on a range of values classified into high, moderate, and low categories.

Theoretically, the improvement in conceptual understanding occurs because virtual reality media provide a concrete learning experience through three-dimensional visualization. [25] Students can directly observe physical phenomena, thereby helping to build clearer mental representations. STEM-based learning also encourages students to relate concepts to real-life situations, thereby enhancing their conceptual understanding more deeply [26].

The results are consistent with those of research [30] that indicates the application of virtual reality and the STEM method can improve the conceptual comprehension. Technology-based media can provide better visualizations of abstract concepts and the STEM approach helps pupils to relate concepts to real life circumstances. Therefore, the use of virtual reality along with STEM is a beneficial innovation in the field of physics education.

4. Conclusion

The research findings and discourse indicate that the developed STEM-based virtual reality media is both viable and effective in improving 10th-grade students' conceptual comprehension of work and energy concepts. This is evidenced by the validation results from experts indicating that the VR media falls into the feasible category, as well as the improvement in students' conceptual understanding shown by the N-gain value in the moderate category. Additionally, the responses from students and educators also indicate that the developed media is engaging to use in learning. However, this research has several limitations, including the relatively short implementation time, the limited number of samples, and the challenges that arose during the implementation process. Therefore, it is recommended that future research involve a broader sample to obtain more diverse results, as well as develop virtual reality media for other physics topics, not just work and energy.

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References

[1] Nurhayati, Lubis L S P, Kusyani D, Harahap Y M and Nurlela 2025 Pengembangan Media Pembelajaran Virtual Reality untuk Meningkatkan Keterampilan Menulis Teks Laporan Hasil Observasi pada Siswa SMP *GHANCARAN J. Pendidik. Bhs. dan Sastra Indones.* 794–809

[2] Oktarizka D A and Abidin Y 2024 Analisis Kebutuhan Pengembangan Media Virtual Reality Sistem Pencernaan untuk Meningkatkan Berpikir Kritis Kelas V SD *J. Elem. Edukasia* **7** 2225–35

[3] Syarah Syahiddah D, Dwi Aristya Putra P and Supriadi B 2021 Pengembangan E-Modul Fisika Berbasis STEM (Science, Technology, Engineering, and Mathematics) pada Materi Bunyi di SMA/MA *J. Literasi Pendidik. Fis.* **2** 1–8

[4] Langendorf R, Susanne Schneider and Frederic V. Hessman 2022 Learning and Teaching Astronomy with Digital Tools promotes Physics Student Teachers' digital Competencies *Astron. Educ. J.* **02** 1–12

[5] Ridwan Nur Cholis M and Yulianti D 2020 Pembelajaran Fisika Berbasis Science Technology Engineering And Mathematics (Stem) Untuk Mengembangkan Keterampilan Kolaborasi **9**

[6] Wulandari R Y, Muhlis M and Handayani B S 2023 Model Pembelajaran Science, Technology, Engineering, and Mathematics (STEM) Berbasis Proyek dalam Pemahaman Konsep Siswa SMAN 1 Empang Pada Materi Pencemaran Lingkungan *J. Ilm. Profesi Pendidik.* **8** 1025–34

[7] Yunita, Diani R and Noperi H 2024 Development of interactive e-modules with stem approach using canva application to improve students' critical thinking ability in physics learning *JINoP (Jurnal Inov. Pembelajaran)* **10** 192–210

[8] Nugraha M S, Rosdianto H and Sulistri E 2022 Korelasi Antara Pemahaman Konsep Terhadap

Kemampuan Berpikir Kritis Siswa SMA *J. Phi J. Pendidik. Fis. dan Fis. Terap.* **3** 29
[9] Harnisa S, Risdianto E, Putri D H and Soraya I 2024 Pengembangan Media Pembelajaran Interaktif Berbasis Virtual Reality (VR) Berbantuan Millealab untuk Meningkatkan Hasil Belajar Siswa pada Materi Usaha dan Energi Kelas XI *Navig. Phys. J. Phys. Educ.* **6** 31–41
[10] Mustikasari A, Hindriana A F and Arif A G 2021 Pengembangan Media Pembelajaran Vitual Laboratory Berbasis Android Untuk Meningkatkan Kemampuan Berpikir Kritis Dan Pemecahan Masalah *Edubiologica J. Penelit. Ilmu dan Pendidik. Biol.* **9** 21–6
[11] Nurjanah E, Syafitri Y N V and Aisyah S 2025 Integrasi Simulasi Virtual Reality (VR) Imersif Terhadap Pemahaman Konsep Pengukuran Siswa Sekolah Dasar *Didact. Math.* **7** 330–42
[12] Aminudin S, Rahmawati T and Ismail A Y 2024 Penggunaan Teknologi Virtual Reality dalam Proses Pembelajaran Untuk Meningkatkan Pemahaman Siswa di Indonesia: Sebuah Tinjauan Literatur *Edubiologica* **12** 1–5
[13] Pramasela M and Sefriyanti S 2025 Pemanfaatan Media Virtual Reality Untuk Meningkatkan Pemahaman Konsep Sains Pada Anak Usia Dini *As-Salam J. Stud. Huk. Islam & Pendidik.* **14**
[14] Sugiono 2020 *Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif, Dan R&D)* (Bandung: Alfabeta)
[15] Rayanto Y H, Rokhmawan T and Maulana M Z A S *Penelitian Pengembangan Model ADDIE dan R2D2: Teori & Praktek* (Lembaga Academic & Research Institute)
[16] Branch R M 2010 Instructional Design: The ADDIE Approach
[17] Fatimah S 2025 Pengembangan Media Virtual Reality Geopark Kebumen dalam Pembelajaran IPA untuk Menguatkan Karakter Konservasi Siswa MI *Kappa J.* **9** 291–8
[18] Yuberti and Saregar A 2020 *Pengantar Metodologi Penelitian* (Bandar Lampung: Aura)
[19] Kolopita C P, Katili M R and Yassin R M T 2022 Pengaruh Media Pembelajaran Terhadap Hasil Belajar Siswa Pada Mata Pelajaran Komputer dan Jaringan Dasar *Invert. J. Inf. Technol. Educ.* **2** 1–12
[20] Hake R R and Reece J 1999 Analyzing Change/Gain Scores ed M M and R M American Educational Research Association Division
[21] Wulandari A P, Salsabila A A, Cahyani K, Nurazizah T S and Ulfiah Z 2023 Pentingnya Media Pembelajaran dalam Proses Belajar Mengajar *J. Educ.* **5** 3928–36
[22] Pranatawijaya V H, Widiatry W, Priskila R and Putra P B A A 2019 Penerapan Skala Likert dan Skala Dikotomi Pada Kuesioner Online *J. Sains dan Inform.* **5** 128–37
[23] Harnisa S 2023 Analysis of the Development of VR (Virtual Reality) Based Interactive Learning Media Assisted by MilleaLab to Improve Learning Outcomes on the Material of Free Fall Motion Class XI in SMA Bengkulu City *IJOEM Indones. J. E-learning Multimed.* **2** 110–5
[24] Jawad L F, Majeed B H and Alrikabi H T S 2021 The Impact of Teaching by Using STEM Approach in The Development of Creative Thinking and Mathematical Achievement Among the Students of The Fourth Scientific Class *Int. J. Interact. Mob. Technol.* **15** 172–88
[25] Jiang J and Fryer L K 2024 The effect of virtual reality learning on students' motivation: A scoping review *J. Comput. Assist. Learn.* **40** 360–73
[26] Ariel H, Garduño S, Idalia M, Mart E and Castro M P 2021 applied sciences Impact of Virtual Reality on Student Motivation in a High School Science Course
[27] Al Amri A Y, Osman M E and Al Musawi A S 2020 The Effectiveness of a 3D-Virtual Reality Learning Environment (3D-VRLE) on the Omani Eighth Grade Students' Achievement and Motivation towards Physics Learning *Int. J. Emerg. Technol. Learn.* **15** 4–16
[28] Majda L, Ibrahim N and Waspodo M 2024 Belajar IPA Fisika Menggunakan Laboratorium Virtual
[29] Putri N W S, Agustini K, dantes G R and Sudatha I gde W 2024 Systematic Literature Review: Penerapan Teknologi Virtual Reality dalam Meningkatkan Pengalaman Belajar *Indiktika J. Inov. Pendidik. Mat.* **7** 47–57
[30] Tene T, Marcatoma Tixi J A, Palacios Robalino M de L, Mendoza Salazar M J, Vacacela Gomez C and Bellucci S 2024 Integrating immersive technologies with STEM education: a systematic review *Front. Educ.* **9**