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Integrating virtual reality into interactive learning media for improving science concept mastery in elementary education

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ABSTRACT

This study aims to design and develop interactive learning media integrated with virtual reality (VR) technology to enhance elementary students' conceptual understanding of science, particularly on the topic of the air cycle. The research employed the Lee and Owens (2004) model of instructional design, which includes analysis, design, development, implementation, and evaluation stages. The resulting product is a mobile learning application accessible via smartphones, featuring a user-friendly interface, multimedia content, learning videos, interactive simulations, and self-assessment quizzes. The VR-based learning environment allows students to explore scientific concepts both independently and collaboratively under teacher guidance, without spatial and temporal constraints. Expert validation involving media specialists, subject-matter experts, and science teachers indicated high levels of feasibility and appropriateness of the developed media. Field testing with fifth-grade students revealed a significant improvement in their conceptual understanding, as evidenced by increased post-test scores compared to pre-test results. These findings demonstrate that integrating VR into interactive learning media offers an effective approach to support science learning in elementary education and provides a promising direction for immersive digital pedagogy.

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INTRODUCTION

Elementary School (SD) is an educational institution that organizes a 6-year education program for children aged 6-12 years. Education in SD aims to provide students with the ability to acquire knowledge, attitudes, and skills that are appropriate to their level of development. Learning is one component in an education system to achieve these educational goals. Learning is the presentation of a curriculum that demands the effectiveness of an educator in realizing it. Educators must be active in developing and creating student activities according to the program they have created. The success of the learning program can be seen from the success of students in achieving educational goals. To achieve the desired learning outcomes, it can be improved through students' understanding of concepts. The ability to understand concepts needs to be given to students because it will make it easier for them to remember the lesson material presented by the teacher.

Conceptual understanding is the ability of students to understand the information given by the teacher in its entirety, not just knowledge, but also understanding these concepts in a way that can be applied in everyday life (O.D.N. Jannah, N. Fajrie, dan D. Kurniati 2023). The definition of a more comprehensive conceptual understanding according to Bloom is the ability of students to grasp the meaning such as expressing the material that has been presented in a form that is easier to understand, being able to show interpretation and being able to

apply it (Astuti, L.S, 2017, p.42). This is in line with (Novanto et al. 2023) that the ability to understand concepts is the ability to interpret or take concepts and information with proper understanding, drawing conclusions from that understanding in the form of letters, numbers, pictures, symbols and others. Based on some of the explanations above, it can be seen that conceptual understanding is the ability of students to understand the information given by the teacher and be able to interpret it in their own language in an easier and more precise form in taking concepts and information.

The current problem is that students often have difficulty understanding the material during the learning process, especially in science subjects that use a lot of terms that make students afraid to study science material. In line with this opinion, Yolanda & Meilana (2021) stated that science can be categorized as a discipline that is quite challenging and difficult for elementary school students. Science learning teaches students how to solve problems, understand concepts, draw conclusions, work together, be honest, and respect the opinions of others. Some skills that need to be considered in science learning include understanding concepts.

Science is a compulsory subject in elementary school. By studying science, it is expected that students will be able to master a number of competencies that have been set. In schools, science learning must prioritize understanding and comprehension. Strong concepts that can be applied in everyday life can make science learning in schools more useful. In addition, science learning at the elementary school level is expected to produce children who are aware of the development of science and technology in this modern era (Harefa et al. 2022).

The fact is, students may not understand the concept of science well. This fact can be seen from the Trend in International Mathematics and Science Study 2015 in (Hadi & Novaliyosi, 2019) that in the science aspect, Indonesia obtained an average score of 397 which means it is still below the international average and ranked 44 out of 49. Based on these data, improvements are needed because students' ability to understand science concepts is still relatively weak.

Findings at SD Plus Sunan Panadanaran, students' understanding of science is very low. Based on the results of interviews with grade V teachers who teach science subjects, it is known that the results of students' science learning, more than 50% of the total number of students in grade V get learning results below the minimum completion criteria on the water cycle material. The teacher admits that there are still many students who do not understand the concept of the water cycle. Students find it difficult to accept scientific vocabulary and students tend to memorize the material. Meanwhile, information from students interviewed by researchers, science learning that often takes place and is taking place still focuses on the teacher (teacher center), thus reducing student participation. Based on this, it is also supported by the teacher's statement that the discussion of the material only focuses on student books and taking notes on the material. The use of technology is also rarely done. It is known that the use of technology in 1 semester learning can only be done once, due to limited technology and the teacher's ability to operate technology. Based on the researcher's observations in class, it is known that teachers do not provide enough space for students to ask questions, due to the limited time used to take notes on a lot of material, thus triggering a negative impact on students who do not understand the information.

Learning success is influenced by several factors, one of which is the teacher factor. Learning success depends on the teacher. Learning in the 21st century emphasizes novelty or innovation that can create meaningful learning. One form of innovation in education, especially in science learning, is the development of digital devices as an effort to improve learning outcomes.

Regarding the development of digital devices in learning, the role of technology-based learning media is very important to facilitate and expedite education. Therefore, with learning media, learning can be made more effective and efficient (Putri, 2023). Agree with this, according to Fadilah (2023) that learning media is a tool that can be used to help the learning process to be more effective and optimal. Currently the learning process is not only focused on books and blackboards, but there are many learning materials that can be used by teachers as learning media. Many superior features are offered by learning media, both digital and conventional, which can enrich the learning experience of students and help them understand concepts better.

Considering the advancement of technology in the digital era, teachers can use interactive and integrated learning media, one of which is Virtual Reality-based learning media. Virtual Reality (VR) is one of the technologies proposed as a technological advancement that can provide a new form in the world of education. Virtual reality is a technology that allows users to interact with an environment simulated by a computer, meaning an environment that is only in imagination or an environment that is truly imitated (Pranata 2018). Change 4.0 and demands Students want innovative and interesting learning and easier to concretize something abstract. Virtual reality media is one of the 3-dimensional (3D) technology media.

The main advantage of virtual reality is to provide an experience to users, especially students, to feel abstract things, concretized in the sensation of the virtual world. The use of interactive learning media based on virtual reality can visualize the concept of water cycle material in three dimensions (3D). Based on research (Dewi 2020) entitled "Utilization of 3-Dimensional Media Based on Virtual Reality to Improve the Interest and Science Learning Outcomes of Grade V Elementary School Students" obtained data on the average value of students, which was originally 49.55, an average achievement of 82.08 was obtained, meaning that through virtual reality media,

it is possible to concretely show the concepts discussed in the science content that have an impact on students' interests and learning outcomes.

The difference between this study and previous studies lies in the mechanism and type of virtual reality used to support a more concrete and innovative learning process in science subjects, especially water cycle material. The virtual reality media studied is in the form of a learning media application that contains an integration of e-modules, complete guides, water cycle virtual reality videos, water cycle experiment videos and is equipped with quizzes that can all be accessed in one application to support and facilitate students in understanding science lessons, especially water cycle material.

METHOD

This type of research used in developing interactive learning media based on virtual reality is the development model from Willian W. Lee & Diana L. Owens (W.W. Lee & Owens, 2004) which has been modified. There are five stages used in this research, namely (1) Analysis, (2) Design, (3) Development, (4) Implementation, (5) Evaluation. Using this research model can help produce interactive media products and test the effectiveness of the media. Researchers chose this model because it is a model that is specifically designed to develop multimedia (Lee & Owens, 2004: 2). In addition, ADDIE was chosen because it is widely used in learning design practices (Nirmala & Ratnawati, 2024; Ratnawati et al., 2021, 2023; Wulandari & Ratnawati, 2024).

Figure 1. Model development procedure chart by Lee & Owens (2004)

The development of this media product involves several subjects in it such as experts consisting of two lecturers, namely a lecturer in educational technology at the State University of Malang as a material validation expert and a lecturer in Elementary School Teacher Education as a material expert and students of grade V of SD Plus Sunan Pandanaran. Then, the product was tested for practicality on grade V students. The product that was developed was then tested for its feasibility with media validity, material content and practicality. Data from the results of the media, material and practicality validation analysis were obtained from the validation sheet and product assessment with a dichotomous value which means that the answer choices from the instrument sheet distributed to the validator provide yes and no answer choices according to Bahrun, Alifah, & Mulyono, 2018 (in Pranatawiajaya, et al., 2019). The following are dichotomous values with the provisions that, 1) score 1 for the statement "yes", 2) Score 0 for the statement "no". The next step is the average score is calculated by dividing the total score by the number of assessors, which is listed in the following formula:

$$\bar{X}) = \frac{\sum X}{n}$$

Information:

$\bar{X}$ = average score
$\sum X$ = total score
n = total value

The average score is then compared with the quality categories according to the ideal assessment criteria outlined in Table 1.

Table 1. Internal consistency reliability of biology test

No.	Rentan Skor	Kategori
1.	$\bar{X}$ >Mi + 1,8 SBi	Very Good (SB)
2.	Mi+0,6 SBi < $\bar{X}$ ≤ Mi + 1,8 SBi	Good (B)
3.	Mi – 0,6 SBi < $\bar{X}$ ≤ Mi + 1,8 SBi	Good Enough (C)
4.	Mi – 0,6 SBi < $\bar{X}$ ≤ Mi – 1,8 SBi	Not Enough (K)
5.	$\bar{X}$ ≤ Mi + 1,8 SBi	Very less (SK)

Information:

$\bar{X}$ = average final score
Mi = ideal average sought by the formula
Mi = $\frac{1}{2}$ (maximum score + minimum score)
SBi = The ideal standard deviation is sought using the formula
SBi = $\frac{1}{6}$ (maximum score + minimum score)

Then, a product trial with student subjects was also conducted with the aim of testing the readability of virtual reality-based media. Readability response data were obtained from a questionnaire with aspects of material and appearance on the product being developed. The response results from both aspects were divided by the maximum result then multiplied by 100%. The score presentation criteria that indicate the level of ease of readability of the media being developed refer to table 2.

Table 2. Readability criteria

Presentase	Tingkat Keterbacaan	Keterangan
90-100	Very Good (SB)	The material is very easy to understand and the display is very attractive.
75-89	Good (B)	Easy to understand material and attractive appearance
60-74	Good Enough (C)	The material is quite easy to understand and the display is quite attractive.
55-59	Not Enough (K)	The material is not easy to understand and the display is not attractive.
0-54	Very less (SK)	The material is very difficult to understand and the appearance is very unattractive.

The effectiveness of virtual reality-based media on science content, in strengthening students' conceptual understanding at elementary school level is reviewed based on the n-gain score obtained from the pre-test and post-test scores of the experimental and control classes. Interpretation of the increase in students' conceptual understanding abilities refers to the n-gain score criteria which can be seen in table 3.

Table 3. N-gain value criteria

Presentation of Assessment Results	Category
$g \geq 0{,}70$	High
$0{,}30 \leq g < 0{,}70$	Medium
$g < 0{,}3$	Low

Based on the n-gain score obtained by calculating the pretest and posttest values using the formula and interval based on (Hake, 1999). If there are 50% of students who meet the n-gain criteria with a minimum score of 0.3, then the development of virtual reality-based learning media products on science material that is carried out will be considered effective in improving students' conceptual understanding.

RESULTS AND DISCUSSION

3.1. Results

The final product of this development research is interactive media based on virtual reality on the content of science for grade V on the water cycle material. The following is an example of the display of the learning media product that has been developed.

Figure 2. Virtual reality based interactive media display

Virtual-based interactive media contains the subject of science for grade V on the water cycle. This media consists of three main menus. The first is the instruction menu which contains a summary of instructions for users equipped with instruction guidelines via a link button that can be accessed to Google Drive which is a complete guide to using the media that can be accessed via a link. The second is the material menu. Through this instruction menu, users can be helped regarding the buttons on the water cycle learning media along with their respective descriptions. The material menu consists of three submenus, namely the basic competency and core competency

submenus, the water cycle material submenus and the virtual reality submenu. The basic competency and core competency submenus are useful as references for writing materials contained in the application. The material submenu contains e-modules to make it easier for users to learn the water cycle material completely. The virtual reality submenu contains a 3D video of the water cycle process, a quiz game and is equipped with a demonstration video of water cycle learning practices. The application of 3D videos of the water cycle process can be assisted by a tool called VR glasses to visualize water cycle material in cyberspace. 3D videos can rotate 360 ° following the user's direction and are equipped with audio filled by the host to facilitate the explanation of the 3D video.

Figure 3. Water cycle 3D video home screen

In addition to 3D videos, this submenu is equipped with a video demonstration of the water cycle process to support and strengthen the user's conceptual understanding in visualizing the 3D videos that have been viewed. Meanwhile, the last submenu on this virtual reality menu is the water cycle quiz. The quiz provided is in the form of multiple choice with 10 questions. This quiz can be accessed by users after users have carried out a series of activities in the application. Through this quiz, it can help determine students' abilities in understanding the water cycle and help improve students' conceptual understanding. The last menu is the developer profile menu. This menu contains the identity of the developer of virtual reality-based learning media for water cycle material.

In this study, the product feasibility test was conducted by media experts and material experts who have their respective expertise in their fields. Furthermore, the product was tested on students to determine the practicality and success of the objectives of virtual reality media in improving students' conceptual understanding.

Table 4. Virtual reality media validation results by media experts

Aspect	Average score(X)	Interval	Categories
Visual	35	$27 < \bar{X} \leq 36$	Good
Audio	4	$\bar{X} > 3{,}9$	Very Good
Navigation	8	$\bar{X} > 7{,}88$	Very Good
Manipulation	8	$\bar{X} > 7{,}88$	Very Good
Operation	11	$9 < \bar{X} \leq 12$	Good
Effectiveness	4	$\bar{X} > 3{,}9$	Very Good

Based on the table above, it can be seen that the validation of the IPA virtual reality media by media experts has good quality seen from the category of six aspects, namely 2 aspects get a good category and four aspects get a very good category.

Furthermore, after the media validation test was carried out by media experts, it was continued with a media test by material experts. The results of the media test by material experts are as follows:

Table 5. Virtual reality media validation results by material experts

Aspect	Average score(X)	Interval	Categories
Content suitability	44	$30 < \bar{X} \leq 48$	Good
Presentation eligibility	21	$18 < \bar{X} \leq 24$	Good
Language eligibility according to BSNP	31	$27 < \bar{X} \leq 36$	Good
Contextual assessment	23	$20{,}98 < \bar{X} \leq 28$	Good
Suitability of material concepts in VR applications	23	$\bar{X} > 18{,}34$	Very Good

Based on the results of the validation of the material expert, it was found that the product has good quality. This can be proven from the data that of the five aspects of the category, there are four aspects that meet the good category and there is one aspect that meets the very good category, namely the suitability of the material concept

in the application of virtual reality science material on the water cycle. The next stage, a practicality test was carried out by students by giving questionnaires to five fifth grade students of SD Plus Sunan Pandanaran as prospective users of virtual reality media products for science content. Students test the practicality on the smartphone devices they have, then fill out the questionnaire sheets that have been divided. The following is a table of the results of the practicality test of virtual reality media by students, as follows:

Table 6. Virtual reality media practicality test results

Aspect	Average score(X)	Interval	Categories
Visual	35,3	$30 < \bar{X} \leq 48$	Good
Audio	4	$\bar{X} > 3{,}94$	Very Good
Navigation	4	$\bar{X} > 3{,}94$	Very Good
Manipulation	3,7	$2{,}98 < \bar{X} \leq 3{,}94$	Good
Suitability for purpose	12	$\bar{X} > 12$	Very Good
Clarity of instructions for use	12	$\bar{X} > 12$	Very Good
Clarity of performance	12	$\bar{X} > 12$	Very Good
Material	24	$\bar{X} > 24$	Very Good

Based on the table above, it can be seen that the practicality test of virtual reality media has good quality. This can be seen from the eight categories of practicality aspects, there are two aspects that get a good category, namely visual and manipulation aspects. Meanwhile, the other four aspects such as audio, navigation, suitability of purpose, clarity of user instructions, clarity of performance, clarity of material get a very good category.

Furthermore, the data on students' readability responses applied to 5 randomly selected students, get the results of the readability test which can be seen in table 7.

Table 7. Virtual reality media readability test results

Aspect	Indicator	Percentage (%)	Description
Material	Easy to understand for students	95%	Very easy to understand
Display	The display in virtual reality science is interesting	98%	Very interesting
Average		96,5%	

Based on the results of the virtual reality media readability test, namely readability in the material aspect obtained a percentage of 95%, meaning that the material is very easy to understand. Then, readability in the display aspect obtained a percentage of 98%, meaning that the display is very attractive. Thus, the total percentage of the overall readability aspect is 96.5%, meaning that readability in virtual reality-based media on science material is very easy to understand and the media display is very attractive. The effectiveness of the product was tested by applying the experimental method, namely there were experimental classes and control classes. The experimental class is a class that applies learning with virtual reality media. The control class is a class that applies learning with video media. Each class consists of 15 students. Data on conceptual understanding ability was obtained from 20 multiple-choice questions given during the pretest and posttest. The following is a summary of the results of the analysis of students' conceptual understanding ability, which can be seen in table 9.

Table 8. Results of N-gain score of students' conceptual understanding ability

No.	Class	Average Score		Average n-gain (%)	Category
		Pretest	Postest		
1	Experiment	66,3	87,67	63,85 %	Quite Effective
2	Control	60,3	73,67	27,5 %	Not Effective

Based on the results of the n-gain score test calculation, it shows that the average value of the n-gain score for the experimental class is 63.85%, meaning it is in the fairly effective category. While the n-gain score for the control class is 27.5%, meaning it is in the ineffective category.

3.2. Discussion

This virtual reality-based media product is packaged in the form of an application that can be installed on a smartphone. Virtual reality-based applications can be installed on smartphones that have a minimum RAM qualification of 3 GB and have a gyroscope feature. A gyroscope is a feature that has a sensor to track rotation or rotation on a device based on movement. The gyroscope feature is very important to use for the implementation of this development research because the purpose of this research itself is to develop interactive media based on virtual reality. This feature supports real-time tracking of user movements, making interactions in virtual environments more responsive, dynamic, and immersive (Fadilah et al., 2021; He et al., 2024).

The advantage of this interactive learning media product based on virtual reality is its ability to help educators in delivering water cycle material in the science content of grade V elementary schools both online and

offline. This aligns with the characteristics of VR technology, which allows users to interact immersively with visual content, thereby enhancing understanding of complex concepts like the water cycle (Araiza-Alba et al., 2021). One of the unique characteristics of this virtual reality-based media product is that it is packaged in one application that is equipped with various learning supports such as e-modules, complete guides, demonstration videos and quizzes that can function to clarify water cycle material with images, animated videos, materials and practice questions. The presence of 3D video animations simulating the water cycle with VR glasses can attract students' attention in learning. Virtual reality-based media can be called interactive media because it can be used by students independently to learn repeatedly and can be accessed anytime and anywhere. This learning autonomy provides students with the opportunity to interact repeatedly with the content, thereby increasing understanding and long-term knowledge retention (Yadav, 2025). Furthermore, virtual reality has various features integrated into a single application, making it a comprehensive learning medium. This aligns with the opinion of Deliany et al. (2019), who stated that interactive media is a combination of various elements such as images, text, audio, animation, and simulations designed in an integrated manner to clarify material or transform abstract concepts into more concrete forms with the support of assistive devices. The integration of these various features not only increases direct student engagement but also creates an immersive learning experience. Through this technology, students can visualize complex systems, such as the water cycle, in an interactive and immersive manner (AlGerafi et al., 2023). Furthermore, VR applications can simulate real-world phenomena, allowing students to manipulate variables and observe their impacts directly, thus enhancing experiential learning (Li et al., 2022).

This virtual reality-based interactive media can create learning activities that support students to construct their own understanding independently through various methods such as observation, experimentation or experiments that can improve students' conceptual understanding of the water cycle material being studied. This virtual reality-based interactive media was developed to facilitate students' goals in learning science content such as attracting students' interest in this science subject. Students' high interest or motivation to learn can affect the difficulty and ease of students in understanding the concept of a material. A relevant and positive relationship between learning motivation and students' conceptual understanding. Students with strong learning motivation will get maximum learning outcomes. Studies show that interest and motivation significantly influence students' understanding of concepts (Setyani, 2022). Thus, students with high learning motivation tend to achieve better understanding and learning outcomes (Peramita & Hasibuan, 2021). Furthermore, students with strong motivation are also more deeply engaged with the learning material, thus achieving better conceptual understanding and optimal results (Yogi Fernando et al., 2024).

The test results were conducted on the feasibility of the media, media readability, media practicality and the influence of virtual reality-based media on students' conceptual understanding. The feasibility test of this media was obtained from validation by media experts and material experts. Based on the validation results by media and material experts, it shows that virtual reality-based media on cycle material in the science subject of grade V of elementary school shows that the visual aspects and media operation are good and the audio, navigation, manipulation and effectiveness aspects of media use for learning are very good. Meanwhile, based on the validation results from media material experts, it shows that the feasibility of the material content, presentation, and language according to BSNP is good and is declared suitable for use by students in supporting science learning activities on the water cycle material.

Furthermore, a practicality test was conducted by students and the results showed that the practicality test of virtual reality-based media had good practicality quality. Meanwhile, the results of the media readability test obtained a readability percentage of 96.5%, which means that the readability of virtual reality-based media on science material makes it easy for users to understand the material and the display in the media is interesting. This is in line with the research Choirin et al (2024), Darojat (2022), Rahmawati et al (2024) results which state that VR effectively facilitates user understanding and presents interesting content for science materials (Choirin Attalina et al., 2024; Darojat et al., 2022; Rahmawati et al., 2024).

In the next stage, is the testing of the results of the impact of visual reality-based media on the water cycle material on students' conceptual understanding. To determine the impact of the media on students' conceptual understanding is obtained from the calculation of the difference in pretest and posttest values. The pretest value is carried out before the action and the posttest value is carried out after the action. This action is carried out in the experimental class and the control class. The experimental class is a class that applies actions using virtual reality-based media, while the control class is a class that uses video media (without virtual reality-based media).

The pretest and posttest questions were designed to evaluate students' conceptual understanding in the form of 20 multiple-choice questions that focused on seven indicators developed by Anderson & Kartwoll (Anderson & Krathwohl, 2015) including (1) explaining, (2) concluding, (3) summarizing, (4) classifying, (5) interpreting, (6) comparing, (7) giving examples.

The results of the field test showed that there was an increase in students' conceptual understanding of the science content of the water cycle material. This can be seen from the results of the comparative evaluation of the experimental class and the control class. The results of the experimental class showed an average n-gain score

of 63.85%, which means that it obtained a fairly effective category in improving students' conceptual understanding. Meanwhile, the results of the control class showed an average n-gain score of 27.5%, which means that it was not effective in improving students' conceptual understanding.

After going through several feasibility tests, it can be said that interactive media based on virtual reality is feasible to use and is quite effective in improving students' conceptual understanding of the science content of the water cycle material. However, this media also has limitations such as not all smartphones owned by all students support virtual reality-based learning media and applications can run on a minimum of 3GB of RAM. In modern learning, learning media is very important to support science learning. Media can function as a useful tool to provide responsibility or mandate to students to increase learning motivation so that it can affect learning outcomes. This is in line with the opinion of (Wahyuningtyas and Sulasmono, 2020) which states that the learning process carried out by students can improve their learning achievement, because achievement is related to cognitive, affective and psychomotor aspects.

CONCLUSION

Based on the results of research and development of virtual reality-based media, it can be concluded that virtual reality-based media in the science subject of the water cycle material developed is feasible to be used in science learning based on validation from media experts and material experts. This virtual-based media product after going through several tests showed that this virtual reality-based media is quite effective in improving students' conceptual understanding of the science subject of grade V elementary school on the water cycle material. As educators, teachers must follow technological advances and be able to create innovative and creative learning media to support learning activities in the classroom. Learning that provides meaningful experiences to students can increase students' motivation in learning and help students improve learning outcomes.

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