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Enhancing Physics Experience: VIRRE (Virtual Reality of Renewable Energy) to Increasing Concept Understanding and Learning Motivation in Secondary Education

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Abstract

This research aims to develop VR in renewable energy materials (VIRRE) to increase students' concept understanding and learning motivation. This research used Research and Development (R&D) method through ADDIE development model. Validation was carried out to determine the feasibility of VIRRE, then implemented in secondary school students by using problem-based learning model throughout three meetings. Research data was collected through questionnaires and pretest-posttest during classroom learning. The results show that VIRRE has a validity percentage of 94.07% with very valid criteria. The effectiveness of VIRRE media in increasing students' concept understanding and learning motivation is included in medium criteria with n-gain scores of 0.52 and 0.33 respectively. Additionally, VIRRE usage in learning activities showed the most improved indicator of concept understanding and aspect of learning motivation, namely classifying and self-confidence respectively. Moreover, the result indicates that both concept understanding and learning motivation are related to each other, once students are motivated to learn the subject, they can achieve a great understanding of its concept. VIRRE received very good responses from students in aspects of learning activities, materials, and media use with average percentages of 82.22%, 82.7%, and 84.23% respectively. Thus, VR could be an alternative media learning to support educators in delivering physics materials, which are viewed as complicated concepts according to the students.

Keywords: virtual reality, physics, concept understanding, learning motivation, renewable energy

INTRODUCTION

Technology has played an important role in the development of education, one of which is as a learning media that supports the delivery of material to students. Learning media are divided into various types, including learning media that combine audio and visual such as Virtual Reality (VR). VR technology provides opportunities for learners to learn material by interacting in a virtual environment. The principle of VR technology is to block information from the physical environment and bring users into the virtual world (Huang et al., 2019). VR technology as an interactive media can influence the user's senses so they are immersed in a simulated environment to solve complex problems and produce unique, realistic, and practical solutions for students (Mihelj et al., 2014; Sumardani et al., 2020).

In addition to the media side, the context of the material is also a special concern. Renewable energy materials taught to students in the Merdeka Curriculum bring students to play an active role in global

issues and solutions to problems for Sustainable Development Goals (SDGs) (Kemendikbudristek, 2022). This curriculum has been constructed to anticipate: 1) global trends related to rapid improvement of technological advances; 2) socio-cultural shifts; 3) environmental changes; and 4) opportunities for future work, regarding the competition of human resources quality and sustainable educational actions (Wardani et al., 2023). Therefore, the delivery of renewable energy materials needs to be used in everyday life which engages the meaningfulness of learning. Meanwhile, according to the results of research by Musyarrof et al. (2018), students have less motivation to learn physics subjects due to a lack of interest in students and external factors such as learning methods and models that are less interactive in their opinions.

Related to these problems, VR media can be the perfect catalyst to convey complex physics concepts through interesting learning (Budi et al., 2021). VR can help learners acquire cognitive skills through experiential learning, such as exposing them to environments that may be difficult to visit in person (Çalişkan, 2011; Hamilton et al., 2021). The animation, 3D visuals, and may increase user comprehension, improving their understanding of the content (Zhao et al., 2023). Presentation in various forms of representation in the form of images, 3D visuals, tables, graphs, presentations, sample questions, and animations is suitable for use as learning materials to understand physics concepts (Muliyati et al., 2020). VR contains various representations including 3D visuals that can illustrate abstract physics concepts aimed at improving students' conceptual understanding (Bakri et al., 2020). Additionally, consuming VR significantly progresses students' academic performance and increases their innovation (Al Farsi et al., 2021).

Literature studies have revealed a research trend toward the use of VR in physics learning, showing positive growth throughout two recent decades (Citra & Anggaryani, 2022). VR has been riding the development of online education systems and enlarging the educational field more significantly, while students nowadays are more engaged in e-learning (Al Farsi et al., 2021). Research conducted by Kumalasari and Triyono (2018) has added Virtual Physics World which can improve students' daily physics application skills on the topic of rigid body equilibrium. The VREE (Virtual Reality Endogenous Energy) media can motivate students to learn physics on mechanical wave materials (Kartikasari & Anggaryani, 2022). The 3D-VRLE (Virtual Reality Learning Environment) also showed a significant improvement in motivating students to learn physics (Amri et al., 2020). The use of virtual simulations with 3D molecular animation can improve students' mastery of concepts in the Valence Shell Electron Pair Repulsion (VSEPR) material (Stiawan et al., 2022). Moreover, another study has developed VR to enhance STEM literacy in energy concepts, especially for the hydropower plant (Widiyatmoko et al., 2023).

In line with the mentioned studies, this research aims to develop a VR learning media called VIRRE (Virtual Reality of Renewable Energy). VIRRE was developed based on the need for renewable energy teaching materials which are still not widely available due to the demands of implementing the Merdeka Curriculum in schools. VIRRE in this study is also designed contextually so it is more interesting and more instilling the relationship of renewable energy applications than fellow VR media that has been developed before. VIRRE is expected to be applied in learning activities in schools, especially at the secondary education level where students can feel motivated to learn physics. Through contextual-based learning, students are expected to master physics concepts and be able to apply the knowledge they have gained from the learning process at school to the real environment. To achieve the goal, specifically, the researchers aim to gain: a) validity, b) effectiveness, and c) practicality regarding VIRRE as an alternative learning media to increase students' concept understanding and learning motivation.

METHODS

This research used the Research and Development (R&D) method which refers to the ADDIE development model consisting of analysis, design, development, implementation, and evaluation, frequently used to develop the learning media which provides an opportunity to hold implementation in school (Lee & Owens, 2004). This model is adapted as illustrated in the following flow.

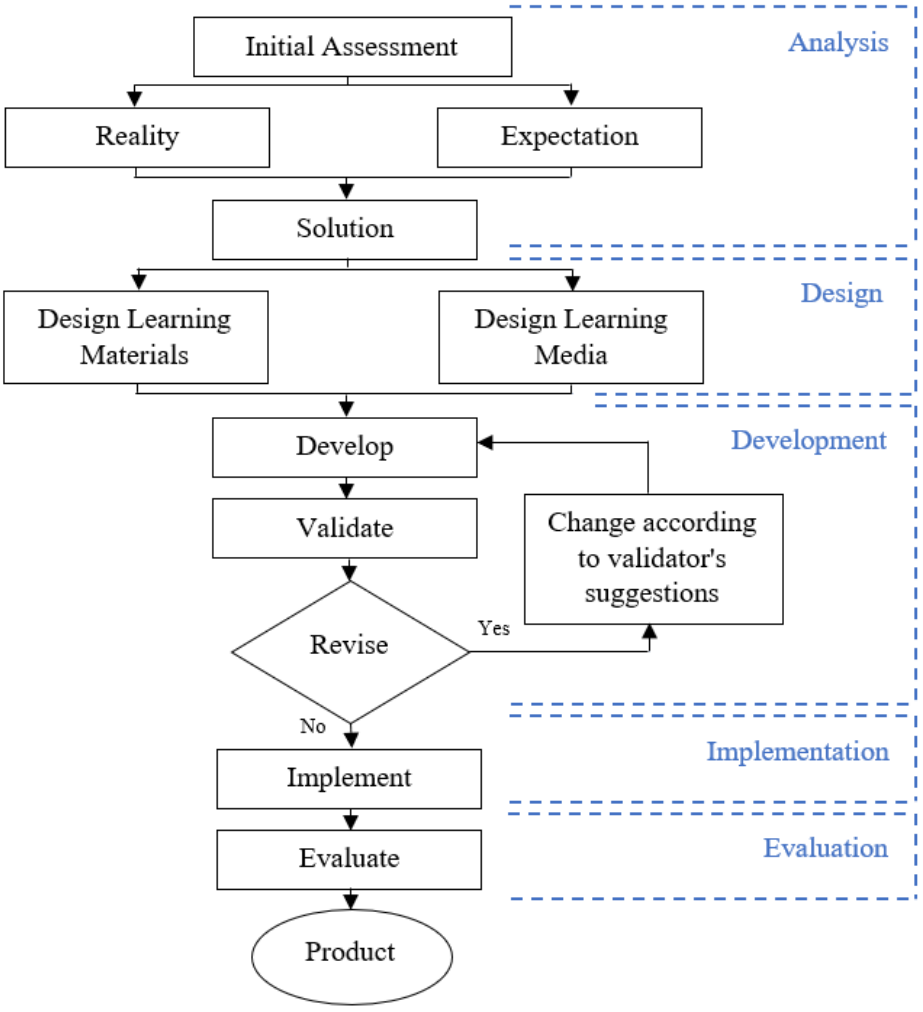


FIGURE 1. Research Flow

(Source: Mulyatiningsih, 2012; Alifteria and Anggaryani, 2021)

Analysis Stage

At this stage, analysis of initial conditions was carried out to determine the potential and problems of the research, learning material, and the restrictions on research objects.

- Potential and problem of research
  This analysis is used to determine the problems that arise during learning. The development of learning media should be based on real conditions in school.
- Material
  The aspects of materials were analyzed to find the material points and learning outcomes that the curriculum taught in school.
- Object
  Specifications of the media were developed against the materials so that research objectives could be achieved.

Design Stage

Following the analysis, researchers built a prototype of VIRRE to support the achievement of students' learning process. The creation of VIRRE was developed using the Millealab platform, using various 3D assests related to renewable energy sources. VIRRE was designed by applying contextual concepts based on renewable energy materials. This VR was constructed in the purpose of delivering

the effect of non-renewable sources and comparing differences of renewable sources to overcome the energy issued in the first place.

Development Stage

To maximize VIRRE constructed in the previous stage, research aimed to produce learning tools that support the media in learning activities. Learning media and physics learning experts validated VIRRE and learning materials. For VIRRE, there were seven aspects of media learning validated by the experts, including visual, interest, useful, accurate, legitimate, structure, and language use of the media. The results of validity were used to revise the media until it was declared valid and could be applied in learning activities. Validation assessments used the Likert scale as presented in TABLE 1.

TABLE 1. Likert Scale

Score	Criteria
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

(Riduwan 2012)

Validation percentages were calculated by descriptive-quantitative analysis in presented formula.

$$P(\%)=\frac{n}{N}\times 100\%$$

where: n is the total average score of assessment aspects and N is the maximum score for assessment aspects (Riduwan 2012).

The assessment criteria of the average percentage score for validity data are presented in TABLE 2 as follows.

TABLE 2. Interpretation of Validation

Percentage (%)	Criteria
≤ 20.99	Very Invalid
21.00 – 40.99	Invalid
41.00 – 60.99	Acceptable
61.00 – 80.99	Valid
81.00 – 100.00	Very Valid

(modification from Riduwan 2012)

Implementation Stage

At this stage, learning activities, consisting of three meetings, were carried out using the one-group pretest-posttest design. The subject of this research was students from one class in the first grade of senior high school. Students were allowed to use VIRRE and complete existing missions according to the worksheets. Problem-based learning model was used throughout the entire learning process, providing the students about energy issues in the beginning before landing to various renewable energy sources and deciding what is the best source to overcome the problem. Students conducted a series of pre-test and post-test in the second and third meetings, when the materials told about renewable energy sources, to determine whether or not there was an increase in students' concept understanding of renewable energy materials after using VIRRE. Pre-test was given at the beginning of the learning, while post-test was given at the end of the meeting. Both of tests were given as essay questions which allow them to analyze the characteristics, potentials, advantages, and disadvantages of renewable energy source. Students also filled out learning motivation questionnaires before and after using VIRRE which related to their experiences that have been felt when using the media.

Evaluation Stage

Following the research results, an analysis was carried out related to the implementation of VIRRE in learning activities. The results of this analysis could be used as material for the researcher's evaluation of VIRRE that has been developed. Evaluation is needed so that researchers can assess the achievement of VIRRE and find what things can be done to improve the shortcomings in the media.

Concept Understanding

Pretest and posttest assessments were conducted using concept understanding score criteria from Abraham et al., (1992).

TABLE 3. Concept Understanding Level Assessment Score

Degree of Understanding	Criteria for Scoring	Score
No response	• Blank • Responses with "I don't know" • Responses with "I don't understand"	0
No understanding	• Rewrites question • Irrelevant or unclear response	1
Specific misconception	• Responses that include illogical or incorrect information	2
Partial understanding of specific misconception	• Responses that show understanding of the concept but also make statements that demonstrate misunderstanding	3
Partial understanding	• Responses that include at least one of the components of the validated response, but not all the components	4
Sound understanding	• Responses that include all components of the validated response	5

(Abraham et al., 1992)

Prerequisite tests were performed against test scores to see the distribution of the data. The prerequisite tests consisted of normality and homogeneity tests which were analyzed by SPSS software. Then, the test scores were analyzed with an n-gain test which was used to see the effectiveness of VIRRE in improving students' concept understanding of renewable energy materials.

The results of n-gain test were calculated by the following formula.

$$\text{N Gain<g>} = \frac{S_{posttest} - S_{pretest}}{S_{max} - S_{pretest}}$$

where: $S_{posttest}$ is the average of students' post-test score, $S_{pretest}$ is the average of students' pretest score, and S_{max} is the maximum score of the test (Hake, 1999).

The assessment criteria of n-gain test are presented in TABLE 4 as follows.

TABLE 4. N-gain Criteria

Value	Criteria
$g \geq 0.7$	High
$0.3 < g < 0.7$	Medium
$g \leq 0.3$	Low

(Hake, 1999)

Learning Motivation

The questionnaire was given to students to assess their level of learning motivation. Assessment of student motivation questionnaires using the Likert scale as in TABLE 1 and the results were calculated by descriptive-quantitative analysis as conducting validation calculation. Prerequisite tests, normality

and homogeneity tests, were also carried out on questionnaire data to see the distribution of the data. Then n-gain test was carried out to see the effectiveness of VIRRE in increasing students' learning motivation. The n-gain criterias are shown in TABLE 4.

Student Response

Students also assessed the use of VIRRE in learning activities regarding their experiences while studying by using this media. Students scored each statement on a response questionnaire using the Likert scale as shown in TABLE 1 and the results were calculated by descriptive-quantitative analysis as in conducting validation calculation. The interpretations of student response questionnaire scores are listed in TABLE 5.

TABLE 5. Interpretation of Response Questionnaire

Percentage (%)	Criteria
≤ 20.99	Very Poor
21.00 – 40.99	Poor
41.00 – 60.99	Fair
61.00 – 80.99	Good
81.00 – 100.00	Very Good

(modification from Riduwan 2012)

RESULTS AND DISCUSSION

The following are the results of each step of VIRRE development to improve students' concept understanding and learning motivation that have been carried out.

Analysis

At this stage, an analysis of students' learning experiences at school was carried out. In addition, researchers also conducted a study of the school curriculum, namely the Merdeka Curriculum, to determine the material that would be applied in developing media. The following are the results of the analysis as the foundation of VIRRE development.

- Potential and problems of research
  One of the problems is the lack of students' concept understanding and learning motivation towards physics. While the school has applied technology-based media in learning, their learning media is less varied and less interactive, not enhancing contextualized experiences. Therefore, VR-based media can be a solution to bring new experiences for students in learning physics.
- Materials
  Renewable energy is included in phase E of the Merdeka Curriculum. The material also provides subject matter related to work and energy. Students are given a variety of renewable energy sources as an alternative to coal and petroleum which harm the environment.
- Object
  The material applied to VIRRE focuses on renewable energy sources. The developed media will present the working principle of power plants in converting renewable energy into electrical energy. Thus, VIRRE can help students understand the concepts and motivate them to study physics, especially in renewable energy materials.

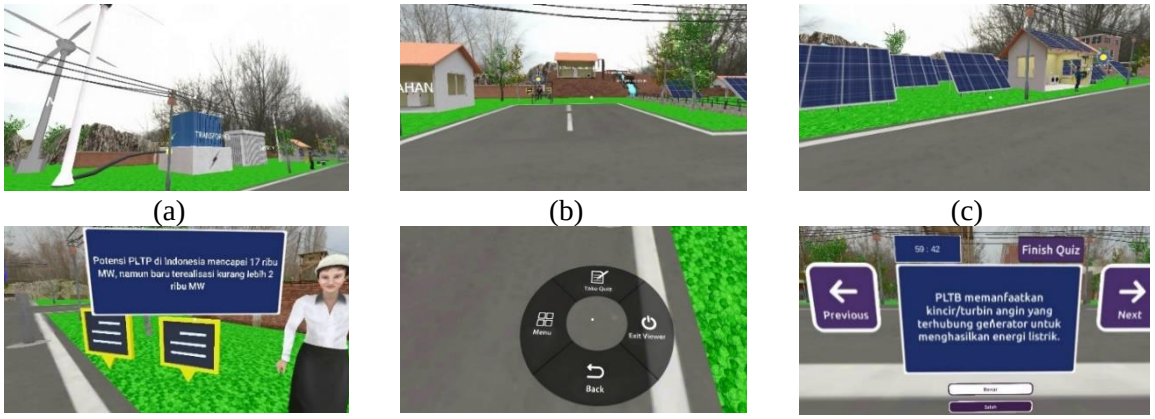
Design

VIRRE presents three scenes which are divided into three meetings. Students can explore VR by hovering over the standpoints. The first scene presents the problem of using non-renewable energy (petroleum and natural gas). The second and third scenes present various renewable energy options as alternative energy to answer the problems in the first scene. Each scene is equipped with text and video

that explain various alternative energies to students from each standpoint. In addition, the second and third scenes are also equipped with quizzes about the presented materials in the scene.

(a) (b) (c)

FIGURE 2. First scene: a) explanation of steam power plant, b) use of motor vehicle fuel, c) impact of motor vehicle fuel



(a) (b) (c)
(d) (e) (f)

FIGURE 3. Second scene: a) wind power plant, b) hydroelectric power plant, c) solar power plant, d) steam power plant explanations, e) and f) quiz features

(a) (b) (c)

FIGURE 4. Third scene: a) nuclear power plant, b) bioenergy, c) use of electric car

Development

The validity test was carried out by two learning media experts and one learning innovation expert. Validation assessments were carried out on aspects of learning media development. The visual aspect assesses the visualization of renewable energy materials and the quality of presented multimedia on VIRRE. The interest aspect assesses the attractiveness of the virtual world design, 3D animation, and real-world representation, as well as the involvement of the user's senses in the use of VIRRE. The useful aspect assesses the usefulness of VIRRE in learning renewable energy materials, triggers learning motivation, supports the formation of Pancasila student profiles, and increases student activeness towards energy issues. The accurate aspect assesses the suitability of the material in VIRRE with the learning outcomes of the Merdeka Curriculum and facts in real life. The legitimate aspect reviews whether the application can be operated properly, including the use of features in the application and the contextual value of the VIRRE design. The structured aspect assesses the layout of the content and the ease of running the application. The discussion aspect assesses the accuracy and effectiveness of sentence structure in VIRRE.

TABLE 6. Validity of VIRRE

Aspects	Average Validator Score			Average Percentage of Score	Validity Criteria
	V1	V2	V3		
Visual	4.60	4.80	5.00	96.00	Very Valid
Interest	4.40	4.80	5.00	94.67	Very Valid
Useful	4.50	4.75	4.00	88.34	Very Valid
Accurate	4.67	4.67	5.00	95.56	Very Valid
Legitimate	4.50	4.75	5.00	95.00	Very Valid
Structured	4.33	4.67	5.00	93.33	Very Valid
Language	5.00	4.67	4.67	95.56	Very Valid
Average Percentage				**94.07**	**Very Valid**

TABLE 6 shows that the average percentage of VIRRE validity obtained a value of 94.07% which is included in very valid criteria. It was obtained that VIRRE can be used for learning media in school. The suggestion from the validator to improve VIRRE is to add activity objectives obtained from the learning achievement indicators to the description of each scene. The validator also suggested distributing material explanations from all standpoints so the students would get information from each of them. Once the activity objectives and content distribution have been added, VIRRE is ready for use in the implementation stage in school.

Implementation

The learning activities were conducted on 37 students of grade X students in one of the high schools in Sidoarjo. One group pretest-posttest method was used in classroom learning design. Learning activities are carried out in as many as three meetings by using problem-based learning model. The first meeting was conducted by introducing the use of VIRRE and bringing students to problems related to the use of non-renewable energy. At the second meeting, students used VIRRE to identify each power plant with energy sources derived from nature, including wind, water, solar, and geothermal. At the third meeting, students continued their exploration by identifying each power plant sourced from chemical reactions, namely nuclear and bioenergy. In the end, students also conducted a discussion about the proper alternative energy to be applied in their city, overcoming the problem in the first meeting.

FIGURE 5. Students used VIRRE and wrote on worksheets

FIGURE 6. Students did test

FIGURE 7. Discussed the results of student work

Evaluation

Pretest-posttest data is used to determine the increase in students' concept understanding while learning motivation questionnaire data to determine the increase in students' learning motivation after participating in VIRRE-assisted learning. Before analysis with the n-gain test, both types of data were carried out as prerequisite tests consisting of normality and homogeneity tests.

TABLE 7. Chi-Square Normality Test Results

	Aspects	Treatment	Frequency	Number of interval classes	χ^2_{count}	χ^2_{table}	Conclusion
1	Concept Understanding	Pretest	37	7	3.74	9.49	Normally Distributed
		Posttest		6	6.42		
2	Learning Motivation	Pre-learning		6	4.37	7.82	
		Post-learning		6	4.74		

(Remark: $\alpha = 0.05$)

TABLE 8. Barlett Homogeneity Test Results

	Aspects	Treatment	Frequency	χ^2_{count}	χ^2_{table}	Conclusion
1	Concept Understanding	Pretest-Posstest	37	0.09	3.84	Homogeneously distributed
2	Learning Motivation	Pre-learning-Post-learning		1.06		

(Remark: $\alpha = 0.05$)

The normality test against the pretest and posttest results was carried out through a chi-squared test. The sample used in this study is said to be normally distributed if $\chi^2_{count} \leq \chi^2_{table}$ with $\alpha = 0.05$. The normality test results against pretest and posttest values produce a value of $\chi^2_{count} < \chi^2_{table}$. Therefore, the data of students' concept understanding test is normally distributed. Meanwhile, the results of the normality test on the learning motivation questionnaire score before and after learning produced scores $\chi^2_{count} < \chi^2_{table}$. Therefore, the data of students' motivation questionnaires is normally distributed.

The homogeneity test was carried out through the Barlett test. The homogeneity test is used to see whether the study sample comes from a population that has the same variant or not. The sample used in the study is said to be homogeneous if $\chi^2_{count} \leq \chi^2_{table}$ with $\alpha = 0.05$. The homogeneity test results of the pretest and posttest produce a value of $\chi^2_{count} < \chi^2_{table}$. Therefore, the study sample is homogeneously distributed. Meanwhile, the results of the homogeneity test on the learning motivation questionnaire scores before and after learning produced scores $\chi^2_{count} < \chi^2_{table}$ Therefore, the data of the student motivation questionnaire is homogeneously distributed. Thus, the sample in the study tends to have no difference so that outside factors that affect the results of the study can be minimized.

Concept Understanding

The average pretest score of students is 42, while the average posttest score of students is 71. Based on the calculation results, it was found that the average n-gain is 0.52, which according to Hake is included in the medium criteria.

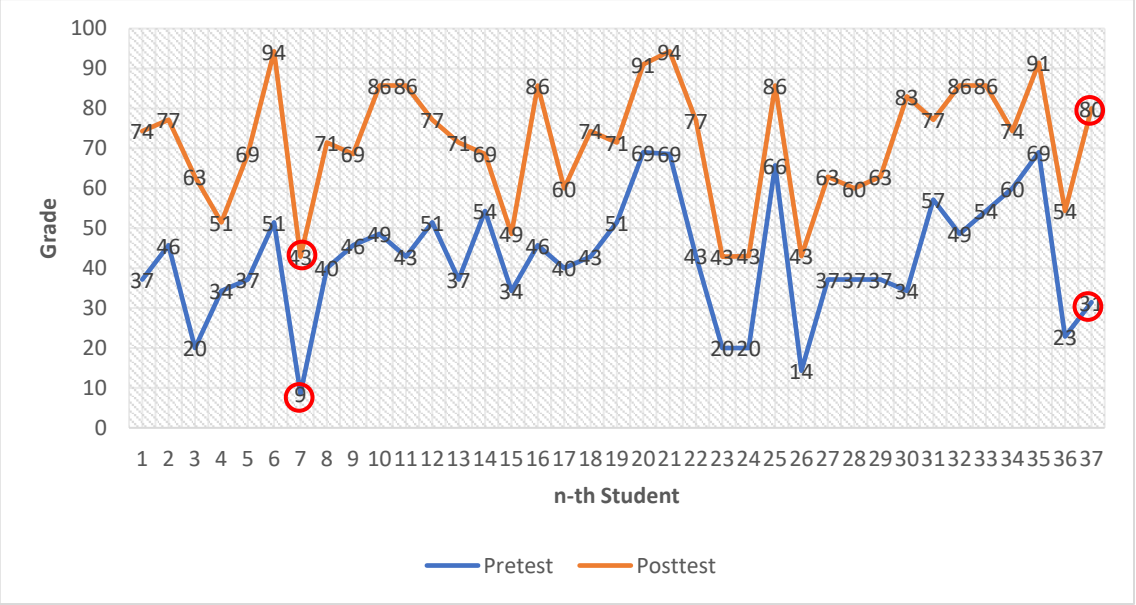


FIGURE 8. Distribution of pretest and posttest scores

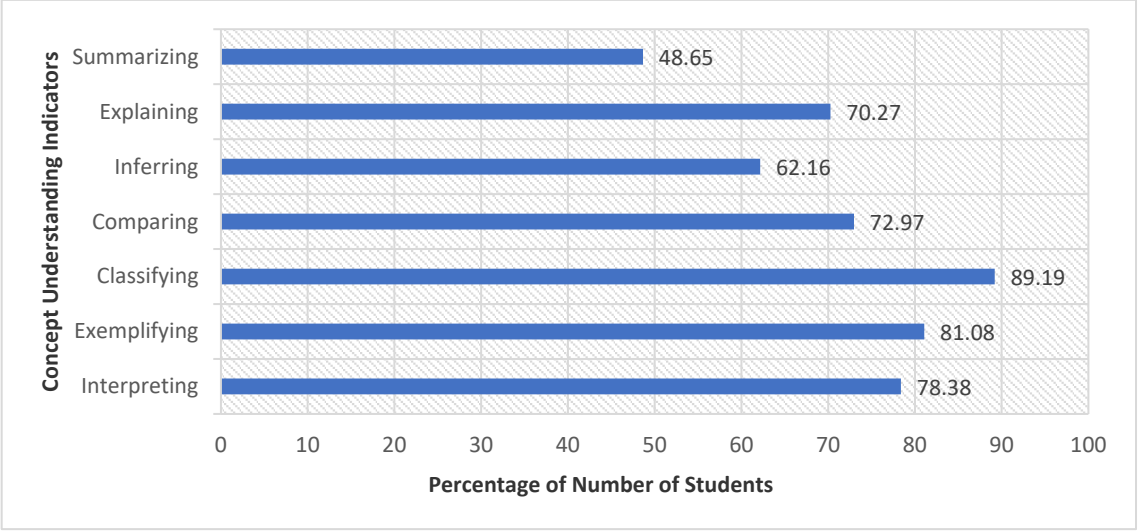


FIGURE 9. Percentage of increase in test scores based on concept understanding indicators

FIGURE 8 shows that all students have higher posttest scores than their pretest scores. For example, student number 7 who previously had the lowest score turned out to have an increase in value after using VIRRE. Student number 37 also experienced a significant increase in scores after using VIRRE. Thus, all 37 students experienced an increase in concept understanding of renewable energy materials. This is in line with the results of research by Saputro and Setyawan (2020) which shows that the use of VR media can improve student learning outcomes in cognitive aspects. The pre-test and post-test questions consist of seven questions, each of which represents seven indicators of concept understanding owned by Anderson and Krathwohl (2001). FIGURE 9 shows that students experienced the most improvement in classifying. Based on this, after participating in learning with the help of VIRRE, students experience the most improvement in determining that something belongs to a certain category (Anderson & Krathwohl, 2001).

Learning Motivation

The average student pre-learning motivation score is 75, while the average student post-learning motivation score is 83. Based on the calculation results, it was found that the average n-gain is 0.33, which according to Hake is included in the medium criteria.

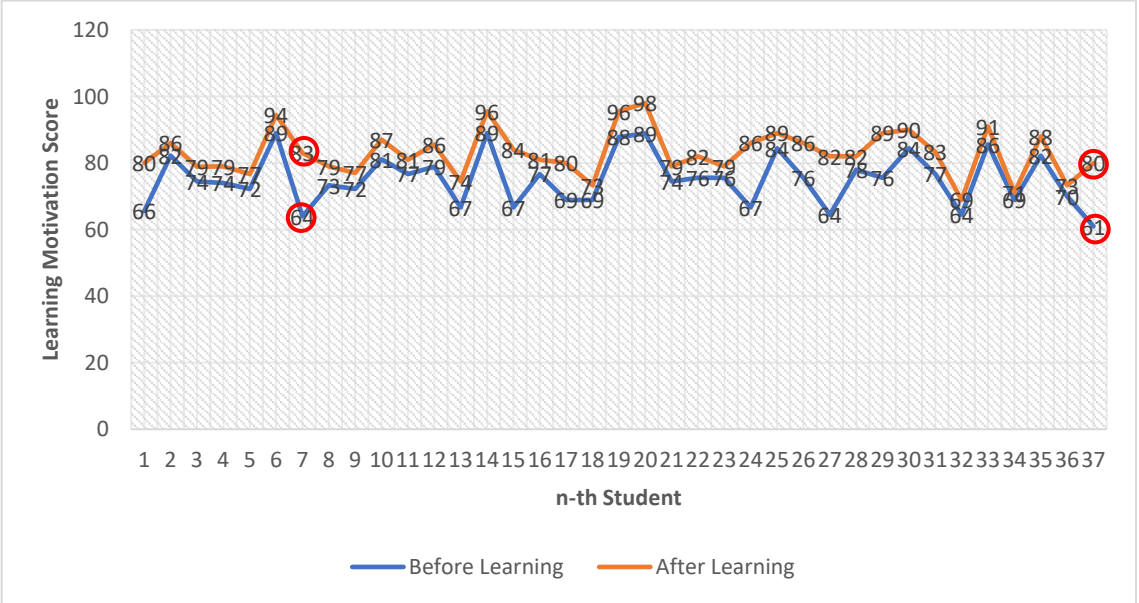


FIGURE 10. Distribution of student learning motivation scores

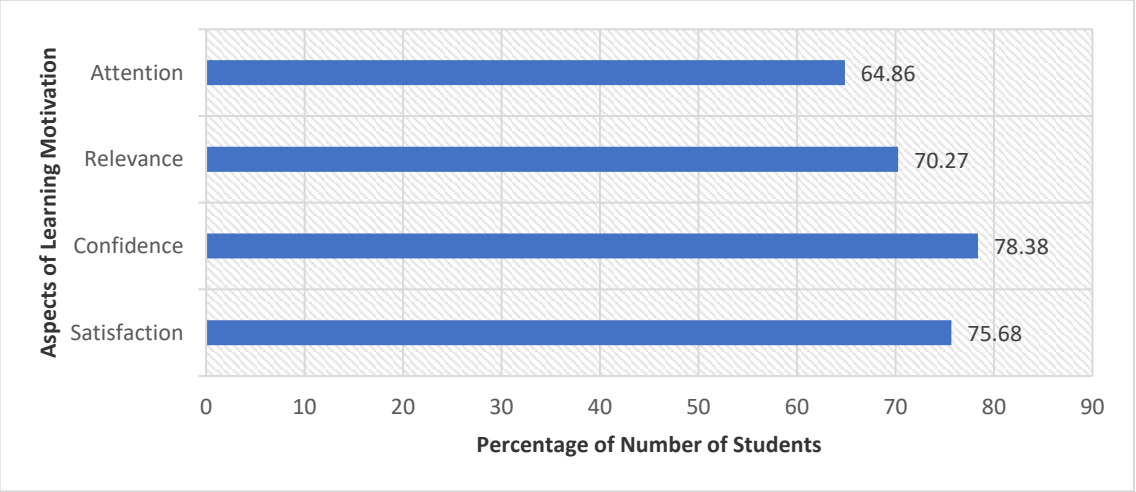


FIGURE 11. Percentage of increase in learning motivation scores based on aspects

FIGURE 10 shows that all students have a higher post-learning motivation score than their pre-learning motivation score. Thus, all 37 learners experienced an increase in learning motivation. This is in line with the results of Kartikasari and Anggaryani's (2022) research which shows that the use of VR can motivate students to learn physics. In addition, it can be seen that students number 7 and 37 experience a significant increase in learning motivation. Both students also experienced a significant increase in concept understanding. This shows that there is a relationship between increased learning motivation and increased concept understanding. FIGURE 11 shows that students experience the most increase in learning motivation in the aspect of self-confidence. Based on this, after participating in learning with the help of VIRRE, students experience the most confidence in solving physics problems (Keller & Thomas, 1987).

Moreover, these results can be a foundation for constructing future research regarding virtual reality in broader fields of physics learning. For instance, researchers could expand the scope of other learning outcomes, such as critical thinking skills, problem solving skills, technological literacy related to science, STEM learning, or collaborative learning. Additionally, long-term studies to assess retention of knowledge and sustained motivation could offer valuable insights into the lasting effects of VR-based learning tools in engaging physics learning. Virtual reality such as VIRRE also can be developed in other objectives from the curriculum, especially in science subjects that need further visualization of their concepts, providing many opportunities for educators to build their own virtual worlds.

Student Response

The response questionnaire was given at the end of the third meeting after the entire learning activity had been completed. Student response questionnaires can be divided into three parts, namely responses to learning activities, materials, and the use of VIRRE.

TABLE 9. Students Responses to Learning Activities

	Aspect	%	Criteria
Learning Activities	Understanding learning objects	84.86	Very Good
	Systematic	83.24	Very Good
	Working on worksheet	82.70	Very Good
	Discussing in team	81.62	Very Good
	Giving opinions	78.92	Good
	Giving attention	85.41	Very Good
	Expressing pleasure	81.62	Very Good
	Asking questions	80.54	Good
	Conducting evaluations	81.08	Very Good
	Giving conclusions	82.16	Very Good
Average		**82.22**	**Very Good**

According to TABLE 9, eight of ten aspects of learning activities obtain a percentage of more than 81% which is included in very good criteria. Students have understood the purpose of each learning activity. Students can understand the systematics of the worksheet and can adjust question points to standpoints on VIRRE when collecting information. Students can complete worksheets based on the material listed on VIRRE. Students also participated in active discussions in answering every question on the worksheet. According to students, VIRRE made them more focused on learning activities. Students can feel the fun of physics with the help of VIRRE. They also could evaluate and provide conclusions about the materials.

On the other hand, giving opinions and asking questions earned a percentage in the range of 61%-81%. Both aspects are included in the good criteria. Students were quite active in arguing during the discussion session, but some of them still didn't want to give their own opinions directly in front of classmates and had only their group mates express answers. Some students were embarrassed to ask directly to the teacher and chose to ask their friends when they found problems. However, overall, the learning aspect obtained an average percentage of 82.22% which is included in the very good criteria. According to students, VIRRE has gone very well in learning activities.

TABLE 10. Students Responses to Materials

	Aspect	%	Criteria
Materials	Non-renewable energy	85.95	Very Good
	Wind power plant	84.32	Very Good
	Hydropower plant	82.16	Very Good
	Solar power plant	82.16	Very Good
	Geothermal power plant	81.08	Very Good
	Nuclear power plant	81.62	Very Good
	Biomass	81.08	Very Good
	Average	**82.62**	**Very Good**

Overall materials obtain a percentage of more than 81% which is included in the very good criteria. The overall average percentage of 82.7% is included in the very good criteria. This means that students can receive excellent delivery of renewable energy materials that provided by VIRRE.

TABLE 11. Students Responses to the use of media

	Aspect	%	Criteria
Media Use	Operation of media	79.46	Good
	User interface	87.03	Very Good
	Quality of multimedia	78.38	Good
	Suitability between contents and learning materials	85.95	Very Good
	Utility of contents	86.49	Very Good
	Relatability with real life	88.11	Very Good
	Contextuality of contents	87.03	Very Good
	Ability to self-learning	83.24	Very Good
	Legibility	97.30	Very Good
	Communicativeness	95.68	Very Good
	Average	**86.87**	**Very Good**

According to media use aspects, 8 of 10 aspects obtain a percentage of more than 81% which is included in the very good criteria. VIRRE features engaging 3D animations for students, allowing the students to deeply imagine each component when producing electricity from renewable sources. The content listed on the pop-up media which provides text, images, and videos is suitable with renewable energy materials. Students can use every pop-up to gather information from VIRRE very well. The design of VIRRE has taught renewable energy materials with a daily life approach to students very well, providing the principles of each power plant using renewable energy sources to produce electricity. In addition, VIRRE can be accessed via mobile so that students can use the application anywhere and anytime. The use of sentences in VIRRE both in writing on pop-up text and delivered

through videos is easy to understand and communicative so that students can receive the materials well. The questions on quiz feature were readably accepted by students, giving an opportunity to check their understanding directly from the media.

On the other hand, media operation and quality of multimedia gain a percentage in the range of 61%-81% which is included in the good criteria. VR is a media that is rarely used in direct learning in the classroom. Therefore, students need time to learn the media that is new to them. In addition, some students try to use the application first without waiting for an explanation of guidelines from the teacher, causing difficulty in controlling their attention. This takes too long for the teacher to guide the confused students in turn. Despite the operation going well, some features of VIRRE were not very satisfying for students. Specifically, there were several comments conducted from students' responses regarding these issues as presented in the following table.

TABLE 12. Students' statements regarding VIRRE

No.	Aspect	Statements
1.	Time to access the scene	10th student: "*It takes a while to load the scene*."
2.	Distance between pop-ups	6th student: "*Video pop-ups please place them somewhere away from text pop-ups so it will not automatically open text pop-ups behind the video*."
3.	Standpoint	20th student: "*The walk away to the next standpoint is too slow, it is better to be able to run.*"
4.	Pause video	10th student: "*It is hard to pause a video because the button size is quite small*." 11th student: "*Video can't be paused and always starts over*." 32nd student: "*When you want to pause the video, it often suddenly replays from the beginning*."
5.	Video timeline	32nd student: "*Sometimes the cursor presses the timeline itself even though it is above the timeline tag and I am not pressing any part*."
6.	Audio	32nd student: "*It is hard to listen to the video because it collides with the sound of my friend's video*."

Therefore, there are needed adjustments for some standpoint positions and improvements in video features. However, the overall average percentage in this aspect obtained a value of 84.23% which is included in the very good criteria. From the responses that have been described, some inputs that can be given for the further development of VIRRE media are as follows.

- The use of VIRRE will be better if the school provides wifi access for their students.
- Teachers can inform students about utilizing VIRRE in certain scenes before class starts so that lesson time is not taken up too much to wait for the scene to open.
- Teachers can inform students to wear earphones/headsets when accessing VIRRE simultaneously in the classroom so that audio does not collide.
- Constraints related to features in the application can be input to the developer, in this case, Millealab, so that VR applications can be used better in the future.

However, the three aspects of assessment, namely learning activities, materials, and media use, obtain an average percentage of more than 81%, which is included in the very good criteria. Thus, VIRRE can be used in the practical learning of renewable energy materials. This is in line with the results of research by Kartikasari & Anggaryani (2022) and Devianti & Anggaryani (2022) which show that VR media-assisted learning has received a very good response from students.

CONCLUSION

Based on the results that have been conducted, VIRRE is declared very valid with an average percentage of 94.07%. VIRRE can increase students' concept understanding of renewable energy materials with an n-gain of 0.52 which is included in the medium criteria. VIRRE is also able to increase students' learning motivation with an n-gain of 0.33 which is also included in the medium criteria. The indicator of concept understanding that experienced the most significant improvement was

classifying, while self-confidence was the aspect of learning motivation that experienced the most significant increase. In addition, VIRRE received a very good response from students in aspects of learning activities, materials, and media use with an average percentage of 82.22%, 82.7%, and 84.23% respectively. Although VIRRE has very good responses, there are needed adjustments in standpoint positions and improvements in video features. Regarding the audio colliding, students can use earphone while watching the video so its audio does not disturb the others.

However, these results can be the foundation for conducting future research regarding virtual reality with broader aspects in learning activities and long-term studies to maintain the positive effects of the media on the retention of knowledge and learning motivation. Other educators also have the opportunity to develop their own virtual world in other materials while using Millealab platform, paying attention to the feedback presented in this research such as pop-ups and standpoint placement, especially in science subjects requiring further visualization of its concepts.

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