The Impact of Virtual Reality on Creative Thinking Skills and Self-Efficacy in Learning Rotational Dynamics

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***Abstract*—Virtual Reality (VR) technology is the best technology for simply presenting complex information. Learning physics, especially rotational dynamics material, is a problem in itself because it is classified as a difficult category. This study aims to determine the impact of using VR in improving creative thinking skills and self-efficacy on rotational dynamics material. The study used a quasi-experimental design involving 21 students in the control class and 23 students in the experimental class. The results showed that the t-test and Mann-Whitney test produced a significance value (sig) of 2-tailed < 0.05. The t-test results indicate that learning by utilizing VR has a better effect than using Slide Presentation in improving creative thinking skills. In addition, the results of the Mann-Whitney test inform that self-efficacy in learning by utilizing VR is better than learning using Slide Presentation. The effect size of learning using VR in enhancing creative thinking skills and self-efficacy obtained scores of 1.55 and 1.02, which fall into the huge effect category. Thus, learning by utilizing VR is proven to improve students' creative thinking skills and self-efficacy in rotational dynamics material.**

***Keywords*—creative thinking skills, Virtual Reality (VR), self-efficacy**

I. Introduction

Significant technological advances in the 21st century encourage the transition of life from the era of 4.0 to the era of Society 5.0. The era of Society 5.0 is related to the integration of technology in life with the aim of providing convenience in various aspects of life [1, 2]. All lines of life are inseparable from the influence of this revolutionary era, one of which is the implementation of technology in the realm of education [1]. Technological advances aim to encourage every individual to master 21st-century skills in order to compete globally through their application in education. However, the implementation of technology in learning has not been implemented optimally, so there are still gaps in learning in schools to support the mastery of 21st-century skills [3, 4].

One form of 21st-century skill is creative thinking skills. This skill is considered the intellectual ability of humans to find the best solutions through creative ideas in solving problems [5, 6]. Creative thinking skills are important because they are needed to solve complex problems in the best and unique ways [7]. Creative thinking skills also involve the ability to look at problems from different points of view and present them in innovative ways. The ability to think well encourages mastery of complete physics concepts and avoids misconceptions. So, this thinking skill needs to be trained for students to learn.

Researchers have reported on a variety of student outcomes related to 21st-century skills. The creative thinking skills of physics students are still low [8, 9]. Students still have difficulty solving higher-order thinking problems [10]. Students' creative thinking skills in physics learning need to be developed because students still have low creative thinking skills in expressing ideas, formulating problems, and solving problems related to physics learning materials [11]. The lack of learning stimulation among students in the learning process, where the utilization of technology remains passive, and the low level of students' self-efficacy is one of the causes of students' low creative thinking skills. In addition, the limited learning media that supports exploration to develop creative ideas is one of the main obstacles. The limitations of physics learning media on some materials also hinder the creation of an active learning process for students. Students are expected to be able to play an active role as users of learning media, not just as observers of the material delivered by lecturers. With learning media that support independent exploration, students will be more confident and able to develop creative ideas optimally [12–14]. Supporting technology as a learning medium is indispensable to encourage students to be active in learning. This technology is needed to actively support the learning process for students in 3D form and support exploration. One form of this technology is virtual technology.

The technology that is capable of presenting virtual objects as real objects, which has been widely used as a medium in this decade and continues to evolve, is Virtual Reality (VR). VR is one of the best technologies for presenting extensive information and conveying it simply through simulation [15]. VR is designed to involve the senses of motion, touch, listening, and vision [16, 17]. The integration of learning by combining science, technology, and techniques is used to support students' cognitive improvement [18]. The presence of VR technology allows people to interact in the real world. VR modifies the educational process and provides practical teaching to meet students' needs for technology [19, 20]. Simulation, experimentation, and visualization of real phenomena are presented in VR. VR participates in providing renewal to the education sector through the presentation of

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learning in a virtual environment [21–23]. A dynamic environment that presents VR according to the wishes and forms of human interaction in the real world [24]. All forms of limitations in the real world can be realized through VR [25].

The use of VR aims to design real-world objects into the virtual world, present simulations for the learning process, and provide interactive learning experiences [26]. Displaying objects that are difficult to observe can be studied effectively and efficiently using the help of VR [27]. The presentation of 3D objects increases users' interest in learning [28]. The presence of VR technology provides an opportunity to simulate phenomena that are difficult to observe.

The use of media plays a role as a communication medium. Information reception and delivery have diversity in each student's information processing in learning physics. In physics learning, real-time measurement of object positions is difficult to observe in detail. This problem provides limitations on the investigation process of physics learning, such as in rotational dynamics material. Physics learning is ideally oriented towards inquiry to shape students' knowledge [29]. The limitations of experimental activities on measuring the position and speed of objects when rolling on rotational dynamics material are difficult to observe under real conditions. This problem provides a gap for researchers to utilize VR in these experimental activities. State-of-the-art rotational dynamics experimental activities in a virtual environment are able to present changes in data from the movement of objects in real-time. The novelty of this study is that it provides modifications to the ability to present data and control the movement of objects in rotational dynamics experimental activities. Experimental activities in physics are part of creative thinking skills. Student involvement directly impacts students' confidence in understanding physics material, which encourages the improvement of students' self-efficacy.

Self-efficacy is related to the ability of the self to organize a task to achieve a goal. Emotional control and motivation in learning in accordance with the capacity of ability to be part of self-efficacy [30, 31]. A person's learning ability is also influenced by self-efficacy in acquiring knowledge. Good self-efficacy encourages good mastery in learning. Self-efficacy is one of the factors that need to be considered in determining the effectiveness of the learning process can be achieved optimally. However, students' self-efficacy tends to be low when studying physics material. Students often feel worried about physics material that tends to focus only on complex mathematical equations. In addition, students also have concerns about solving problems that are directly abstract in nature, impacting their low self-efficacy. This is due to the previous learning media that only provided material in the form of text and pictures, which was dominated by information about phenomena and equations without being accompanied by evidence. Students' active involvement in learning, as media users, plays an important role in improving understanding, as opposed to simply observing media presentations that can lead to low student self-efficacy, especially when no cases and problems are directly related to evidence. Self-efficacy plays a big role in regulating students' attitudes, emotions, and motivation in utilizing various forms, media, technology, and learning resources to achieve learning goals.

Various forms of media provide a variety of self-efficacy to users. The ability of students to organize the use of media or teaching materials in supporting learning is a success factor that needs to be considered in the learning process. Self-efficacy has become a concern in recent years. Self-efficacy has been studied in several previous studies related to the interconnectedness of the use of technology-based media in supporting learning [32]. VR is one of the latest innovative media that is popularly used in universities to support practical learning. Learning management in a virtual environment provides users with free control in exploring the VR environment in the learning process. Self-efficacy is one of the factors that need to be considered to measure the success of the use of VR in learning. The scope of self-efficacy includes confidence in the ability to perform tasks, confidence in the ability to achieve goals, and confidence in the ability to overcome problems. This factor is a consideration when measuring the effectiveness of VR in learning. Therefore, this researcher will be:

1) How does VR learning affect students' creative skills on rotational dynamics materials?
2) How does VR learning affect students' self-efficacy in relation to rotational dynamics material?
3) How significant is the effect size of VR learning in improving students' creative thinking skills and self-efficacy in the topic of rotational dynamics?

II. Literature Review

A. Slide Presentation

Slide presentations are a learning media used to display text, images, and videos. The primary purpose of using slide presentations is to convey information concisely in bullet points. This media has various application variations, such as PowerPoint, Lectora, Powtoon, and Google Slides, which are frequently used in education. PowerPoint, one of the most popular, has simple features and is easy for all audiences. Slide presentations allow the presenter to deliver learning information in an easy-to-understand way, for example, when explaining the phenomenon of Archimedes' principle through a ship's buoyancy phenomenon [33]. Slide presentations using Powtoon help improve students' understanding of concepts in learning physics [34]. Presentations with Lectora provide convenience in linking pages through images, videos, and web links [10].

The main advantage of slide presentations is their ability to present information systematically and assist students in understanding concepts in a simple form [35]. Slide presentations also support group discussions by making it easier to present information to students [36]. This has a positive impact on improving students' understanding because the information is presented with visual aids that help. However, despite these advantages, slide presentations also have limitations. This media tends to be passive because it only conveys information without actively engaging students [37]. Students become passive recipients of information without much opportunity to interact directly with the material presented. Slide presentations, especially in physics education, do not fully support the exploration of physical phenomena that require direct involvement, such as experiments or simulations [38]. This becomes a limitation in creating a more immersive and interactive learning experience. Therefore, there is a need for media that supports more active and interactive learning to improve students' direct experience in the learning process. One such medium is through VR-based learning.

B. Virtual Reality (VR)

VR is a technology that allows users to experience and interact with computer-generated artificial worlds, creating experiences similar to reality [17]. In VR, users wear headset-like devices equipped with motion sensors to perceive and interact with a three-dimensional digital environment [39]. This technology combines visuals, sounds, and sometimes tactile feedback to create a more immersive experience as if the user were inside the virtual world [40].

The urgency of using VR lies in its ability to create more interactive and immersive learning experiences, especially in educational contexts. VR provides an opportunity to introduce materials or concepts that may be difficult to understand using only traditional methods [41]. The advantages of VR in education include increased student engagement, the ability to repeat learning experiences, and the provision of opportunities to simulate in a safe and controlled environment [24, 42]. This is very important in practical education, where hands-on experience has a great influence on material understanding.

In its implementation, VR can be used in various fields of education, ranging from science, medicine, engineering, history and art [43]. One example of VR implementation in education is creating a virtual laboratory that allows students to conduct experiments without space and cost limitations [44–46]. In the field of science, VR allows students to observe microscopic structures and provides an opportunity to learn through hands-on experience that was previously not possible. The advantages of VR are that it provides iterative learning support and supports the urgency of students' self-confidence in learning. Thus, the implementation of this technology plays an important role in supporting the student learning process in providing support for involvement and confidence that is associated with improving students' skills in education, especially in physics.

C. Self Efficacy

Self-efficacy, introduced by Albert Bandura, refers to an individual's belief in his or her ability to achieve a goal or face a particular challenge [47]. This concept is important in psychology because self-efficacy affects the way individuals think, act, and feel about a situation [48]. When a person has a high level of self-efficacy, they tend to be more confident, more motivated to put in the effort, and better prepared to overcome obstacles that may arise [49]. On the contrary, low levels of self-efficacy can lead to pessimism and easy giving up when faced with difficulties.

Key indicators of self-efficacy include an individual's belief in the ability to control the outcome of his or her efforts, either in the context of a task or a larger goal [50, 51]. Some of these indicators include an individual's perception of his or her ability to complete certain tasks, response to failure, and how much perseverance is shown in the face of challenges [52, 53]. In addition, common sources of self-efficacy consist of direct experience, model observation, social support, and a person's emotional state when facing difficult tasks [54].

Self-efficacy is important because of its influence on individual behavior and decisions. The belief that a person can succeed in a particular task affects the choice of task, the perseverance given, and the extent to which one endures in the face of obstacles [55]. It is also closely related to other psychological aspects, such as intrinsic motivation and capacity to learn. In the context of education or the world of work, self-efficacy plays a big role in improving performance and desired outcomes.

VR technology offers a new contribution to supporting self-efficacy, especially by providing an immersive and interactive learning experience. VR allows individuals to practice skills or face real-life situations in a safe and controlled environment. With VR, one can gain first-hand experience in facing certain challenges without the real risk of failure. This can improve self-efficacy, especially for those who feel less confident in real-world situations. The technology also supports effective model observation and experiential-focused learning, which are important factors in building self-efficacy.

D. Creative Thinking Skills

Creative thinking skills are the ability to generate new ideas, see a problem from various perspectives, and find innovative solutions [56]. These skills involve the ability to think outside the box, develop original thinking, and connect seemingly unrelated information [57]. In the context of education, creative thinking is very important to encourage students to think critically and develop into individuals who are able to adapt quickly in a constantly changing world [58]. Through creative thinking, students can more easily solve complex problems and innovate in various fields [59].

Indicators of creative thinking skills can be seen in the ability of individuals to generate new ideas, find alternative solutions, and have an openness to unusual ideas. A person with creative thinking skills is usually able to think divergently better, is able to see many solutions to a single problem, and can adapt quickly to changes that occur [60]. The ability to design effective and efficient solutions is also an important indicator of a person's creativity. In addition, the ability to collaborate with others to create better ideas is also a determining factor.

The importance of creative thinking skills cannot be underestimated, especially in facing the challenges of an increasingly complex era. Creativity is the key to creating innovation and progress in various sectors, be it in technology, education, art, or business [61]. In a world filled with rapidly evolving information and technology, the ability to think creatively is indispensable so that individuals can not only survive but also thrive. Therefore, practising creative thinking skills must be a priority in human resource development, especially among students and young professionals.

VR technology has emerged as a tool that has the potential to support the development of creative thinking skills and increase self-efficacy. VR allows individuals to experience simulations and situations that cannot be perceived in the real world, thus opening up opportunities for them to explore new ideas and practice problem-solving in various scenarios. In the context of education, the use of technology can help students think more creatively in solving problems, imagining, and developing innovative solutions [62, 63]. With more immersive and realistic interactions, VR technology provides a different and more immersive learning experience, which can increase students' confidence or self-efficacy in overcoming future challenges. The characteristics of VR are aligned with indicators of self-efficacy and critical thinking skills, so this integration is urgent in supporting the learning process. Therefore, VR investigation of students' self-efficacy and creative thinking skills requires further investigation into learning, especially physics.

III. Materials and Methods

A. Design Research

This research uses quasi-experimental methods. The design of this study used two classes that had average similarities. The population of this study consisted of first-year students at Padang State University, consisting of 150 people spread across five classes with an age range of 17 to 19 years. The research sample was randomly selected from the five classes, and two classes were chosen, namely Physics A and Physics D classes, because they had the same average initial ability with an average score of 50 and 51. The two classes are divided into a control class and an experimental class. The experimental learning class used VR, and the control class used Slide Presentation. The research design is presented in Table 1 and Fig. 1.

Table 1. Design quasy experimental

Class	Number	Treatment	Post-test
Control	21 (Student)	Slide Presentation	Test
Experiment	23 (Student)	VR	Test

Fig. 1. Experimental VR and control (slide presentation) class learning design.

Fig. 1 shows the learning forms of the experimental and control classes. In the experimental class, before learning with VR was implemented, students were first given a demonstration of the VR hardware features, namely VR glasses and a joystick. This introductory stage was conducted because the students in this class had not used VR before. After understanding the basic features of VR, the students were introduced to the VR application used to learn about rotational dynamics.

In the experimental class, learning VR related to rotational dynamics in the rolling barrel phenomenon presents information that allows users to vary the conditions of changes in barrel motion. Students, as a whole, use VR equipment to observe the rolling barrel phenomenon and conduct experiments in it. The objects presented in the form of barrels and the height of the field can be varied by students during VR learning. In a VR environment, students can also vary the conditions of inclined planes, both in slippery and rough conditions. VR allows students to vary the roughness of inclined planes and heights. This condition gives students creative freedom to determine the magnitude of the speed and acceleration of the inclined plane that rolls through the data that appears in VR. Meanwhile, in the control class, learning uses Slide Presentation to present learning material through presentations. One of the students was asked to present the learning material while the other student listened to an explanation of the rotation dynamics.

B. Data Collection and Instrument

Data collection in this study used an instrument test of creative thinking skills and self-efficacy. The research instrument used adopts a previous research instrument that has been validated and reliable for measuring creative thinking skills and self-efficacy. There are four indicators of creative thinking skills, with each indicator consisting of one descriptive question. This study's creative thinking skills assessment instrument has been tested for validity and reliability to ensure its quality. The validity test results showed that the r-count values for the 4 questionnaire items were 0.888, 0.924, 0.708, and 0.551, all of which are greater than the r-table value of 0.308, indicating that the instrument was valid. The reliability test using Cronbach's Alpha produced a value of 0.779, indicating that the instrument was reliable. Therefore, the creative thinking skills assessment instrument was valid and reliable, making it suitable for use in the research.

Table 2. Indicators of creative thinking skills [6, 7]

No	Indicators of Creative Thinking Skills
1	Triggers a lot of questions
2	Have a varied idea of the cause of a problem.
3	Able to give birth to unique ideas for a problem solution
4	Able to provide ideas/ideas to solve problems in detail

Table 3. Indicators of self-efficacy

No	Indicators	Sub-Indicators
1	Confidence in the ability to perform tasks	Confidence in the ability to use VR features. Belief in the ability to learn effectively with VR.
2	Belief in the ability to achieve goals	Belief in the ability to understand physics concepts through VR. Belief in the ability to explore physics concepts in depth through VR. Belief in the ability to improve academic achievement through VR.
3	Belief in problem-solving skills	Belief in the ability to overcome difficulties in understanding physical materials through VR. Confidence in facing and solving physics challenges after interacting with VR.

Meanwhile, in self-efficacy, there are three main indicators, with the first indicator consisting of nine questions, the second indicator consisting of nine questions, and the third indicator consisting of four questions. The question is used to reveal the effectiveness of using VR compared to learning with slide presentations in creative thinking skills and self-efficacy. The indicators of creative thinking questions and self-efficacy used are presented in Table 2 and Table 3.

C. Data Analysis Technique

The data was analyzed using SPSS 26. Data analysis includes normality and homogeneity tests. Statistical tests include the t-test and the Mann-Whitney test. Hypothesis zero in this study: there is no significant effect of VR. This applies to students' creative thinking skills and self-efficacy in rotation dynamics. If the value of sig. (2-tailed) < 0.05, then the null hypothesis is rejected.

The researchers calculated the effect size using three key statistical parameters: the average value (x), Standard Deviation (SD), and the number of samples (n). These parameters were collected from both the control class and the experimental class [64]. To compute the effect size, the researchers applied the following equation: (1). The interpretation of the effect size values followed a standard classification system. A value of d = 0.2 was classified as a small effect. A value of d = 0.5 indicated a medium effect, while d = 0.8 represented a large effect. Additionally, d = 1.20 was considered a huge effect, and d = 2.0 signified a very huge effect [64].

$$d = \frac{x_E - x_C}{\sqrt{\frac{(n_E-1)S_E^2 + (n_C-1)S_C^2}{n_E+n_C}}} \tag{1}$$

IV. Result and Discussion

A. VR Learning Affects Students' Creative Skills in Rotational Dynamics Materials

The results of creative thinking skills in both classes are obtained after going through different learning treatments. The control class received learning by using Slide Presentation, while the experimental class used VR technology. After learning, both classes were tested with a post-test using creative thinking skills instruments. The results of the creative thinking skills test on each indicator are shown in Fig. 2.

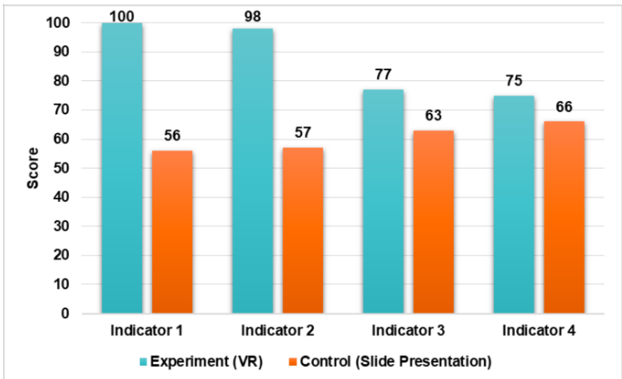

Fig. 2. Results of creative thinking skills.

Fig. 2 presents the results of creative thinking skills in VR learning and Slide Presentation learning. Indicator 1 informs the score on learning with VR of 100 and learning with Slide Presentation 56. The results show that the ability to express many students' questions with VR learning is better than Slide Presentation learning. Indicator 2 informs the score on learning with VR of 98 and learning with Slide Presentation 57. The results show that students who study with VR are able to express various ideas related to this phenomenon. In indicator 3, the score for learning with VR is 77, and for learning with Slide Presentation, it is 63. These results inform that learning with VR is better at encouraging students to generate various ideas for solving problems. In indicator 4, the score for learning with VR is 75, and for learning with Slide Presentation, it is 66. These results indicate that learning with VR is able to provide the main solution to these problems. In general, students' creative thinking skills with VR learning are better than with Slide Presentation learning. Based on the results of the creative thinking ability test, a normality and homogeneity test was carried out on the results of the two classes. The results of this test are used to assess the condition of the data of both classes and are presented in Table 4.

Table 4. Normality test and homogeneity test on creative thinking skills data

Class	Test of Normality		Test of Homogeneity		
	df	Sig.	Levene Statistic	df	Sig.
Control	21	0.074	2.73	42	0.10
Experiment	23	0.057			

If sig > 0.05, then the data is normal and homogeneous.

Table 4 displays the results of the normality and homogeneity test with a significance value (sig) of > 0.05. The normality test result shows that the sig value is 0.057, which is greater than 0.05, which indicates that the data is normally distributed. Furthermore, the results of the data homogeneity test produce a sig value of 0.10, which indicates that the data is homogeneous. In general, the data obtained are normally distributed and homogeneous so that independent tests of samples become advanced statistical tests that can be performed. The results of the independent test of the sample through the t-test are presented in Table 5.

Table 5. T-test table

Class	N	M	SD	Sig.	t_{Count}
Contol	21	85.00	6.030	0.000	10.299
Experiment	23	61.66	8.850		

t_{Table}: 2.021.

Table 5 informs the t_{Count} test value of 10.299, which is greater than the critical value of 2.021, and the significance (2-tailed) < 0.05. This indicates that the null hypothesis is rejected. Therefore, the use of VR is more effective than learning by utilizing slide presentations. The utilization of VR media has a significant influence on improving students' creative thinking skills.

B. VR Learning Affects Students' Self-Efficacy in Rotational Dynamics Materials

Self-efficacy data was obtained from the results of self-efficacy instruments filled in by students. This data contains information about students' self-efficacy towards learning using VR and Slide Presentation. In the control class, the data obtained was in the form of self-efficacy toward learning using Slide Presentation, while in the experimental class, the data obtained was in the form of self-efficacy toward learning using VR. The results of the two data were classed and calculated to see the comparison and influence on learning. The results of students' self-efficacy towards learning in each indicator are shown in Fig. 3.

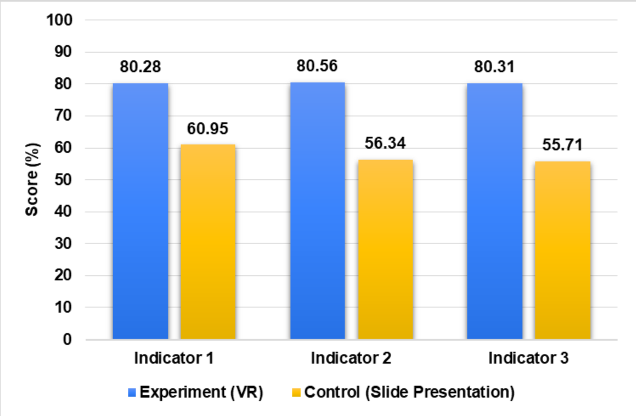

Fig. 3. Results of self-efficacy.

Fig. 3 shows the three main indicators of self-efficacy. In indicator 1, 80.28% was obtained in the learning VR and 60.95% in the learning Slide Presentation. These results indicate that confidence in the ability to perform tasks in learning VR is better than that of learning Slide Presentation. In indicator 2, 80.56% was obtained in learning VR and 56.34% in the learning Slide Presentation. These results indicate that confidence in the ability to achieve goals in the learning VR is better than in the control class. In indicator 3, 80.31% was obtained in the learning VR and 55.71% in the learning Slide Presentation. These results indicate that confidence in problem-solving skills in the experimental class is better than in the learning Slide Presentation. Based on the results of the self-efficacy, a normality and homogeneity test was carried out on the results of the two classes. The results of this test are used to assess the condition of the data of both classes and are presented in Table 6.

Table 6. Normality test and homogeneity test on self-efficacy data

Class	Test of Normality		Test of Homogeneity		
	df	Sig.	Levene Statistic	df	Sig.
Control	21	0.11	54.10	42	0.00
Experiment	23	0.00			

If sig > 0.05, then the data is normal and homogeneous.

Table 6 displays the results of normality and homogeneity tests with a significance value (sig) < 0.05. The results of the normality test showed a sig value of 0.11 in the control class, which was greater than 0.05, and 0.00 in the experimental class, which was smaller than 0.05. Thus, the normality results show that the data is not distributed normally. Furthermore, the results of the data homogeneity test produced a sig value of 0.000, which showed that the data was not homogeneous. In general, the data obtained are not normally distributed and are not homogeneous, so the Mann-Whitney test is an advanced statistical test that can be carried out. The results of the Mann-Whitney test are presented in Table 7.

Table 7. Mann-Whitney test results

Test	Result
Mann-Whitney	135.000
Z value	−2.58
Sig. (2-tailed)	0.010

Table 7 displays a Mann-Whitney U score of 135,000, which shows a significant difference between the results of the post-test of the class with VR learning and the class with Slide Presentation learning. At a significance level of 0.05, the table's Z value is −1.96. The Z value obtained at −2.58 is much smaller than the Z value of the table. The null hypothesis is rejected when the two-sided significance value is less than 0.05, and the obtained Z value is less than the table's Z value. In this case, the value of two-sided significance and the obtained Z-value are much smaller than the established standard value, so the null hypothesis can be rejected. The conclusion of this test is that learning using VR is more effective in increasing students' self-efficacy compared to learning using Slide Presentation on rotational dynamics material.

C. Effect Size Value of Creative Thinking Skills and Self-Efficacy

The implementation of learning by utilizing slide presentations and VR is carried out through effect size analysis. The effect size analysis aims to investigate how much VR implementation affects learning. The measurement of this implementation uses Cohen's effect measures. The results of the effect size measurement are spread across categories that reflect students' creative thinking skills and self-efficacy, as shown in Table 8.

Table 8. Size effect

Variable	*d*	Category
Creative Thinking Skills	1.55	Huge effect
Self-Efficacy	1.2	Huge effect

Table 8 shows the effect size of students' creative thinking skills and self-efficacy. The results of the measurement for creative thinking skills scored 1, which falls into the large effect category. Similarly, the self-efficacy category also scored 1, indicating a large effect. These results suggest that learning with VR has a significant positive effect in enhancing students' creative thinking skills and self-efficacy. Therefore, VR provides a greater impact on learning outcomes than implementing slide presentations in learning physics on the topic of rotational dynamics.

V. Discussion

Implementing learning media in the form of slide presentations and VR contributes to improving students' creative thinking skills. Slide presentations support students' creative thinking skills during physics discussions. This media provides simple information by displaying images or illustrations to explain physical phenomena concisely. Meanwhile, VR-based learning presents a more complete learning experience by involving students directly in the process of exploration and 3D visualization. The results obtained indicate that VR holds significant potential in improving creative thinking skills by creating an immersive, interactive, and exploration-based learning environment. VR enables students to directly interact with objects and concepts that are otherwise difficult to access in the real world. This fosters "out-of-the-box" thinking, which stimulates the development of creative thinking skills [25].

The results of the creative thinking learning tests show that VR learning significantly improves students' creative thinking skills than learning using slide presentations. Learning with VR has a greater impact because it offers direct exploration experiences that slide presentations cannot provide. This is because slide presentations have limitations in supporting interactive learning [65]. This media is less able to facilitate direct exploration of physical phenomena through experiments or personal data collection [36, 66]. Additionally, VR supports simulations and experiments within a safe environment, allowing students to explore various solutions without fear of real-world consequences, ultimately enhancing their willingness to take creative risks [67]. These results are in line with previous research, which showed that learning with VR significantly improves students' creative thinking abilities through the presentation of creative learning in 3D visualization, complementing the shortcomings of previous learning media [68].

Learning using VR on the topic of rotational dynamics provides features that allow students to conduct experiments by varying the values of incline height, object mass, and surface roughness to simulate rotational motion on the object. Additionally, another advantage is that students, as users, are presented with real-time changes in velocity and time measured during the object's movement process. This feature offers exploration for students in uncovering various problems, developing ideas, and finding the best solutions for addressing issues related to an object rolling on an inclined plane. The exploration process in VR contributes to helping students find the best solutions to solve everyday problems related to inclined planes, their benefits, and the best techniques for applying these concepts. The exploration activities presented in VR independently train students' creative thinking skills and improve their self-efficacy through direct simulations in a virtual environment, providing an advantage for VR learning in developing creative thinking skills compared to using slide presentations. The features of VR, such as the ability to interact directly, touch, move, and interact with objects and physics tools in conditions resembling the real world, provide a solution to create more interactive learning [69]. This ability makes VR more effective in enhancing students' creative thinking skills [70]. Due to the interactive nature of VR increases student engagement and motivation to think innovatively, enabling them to experience real-world or fictional scenarios firsthand [71]. This, in turn, helps them develop broader perspectives and improves creativity in problem-solving [72].

The improvement of students' creative thinking skills is greatly influenced by self-efficacy in the learning process. The research findings show that students who learn using VR have better self-efficacy compared to those who use slide presentations. Previous studies have revealed that the adoption of technology in learning influences students' self-efficacy [73]. Students' involvement in operating media and technology is one of the factors that affect their self-efficacy [74]. Self-efficacy encourages students' confidence in achieving learning goals [75]. Learning with VR can also increase students' interest and motivation to learn [70], which, in turn, influences the learning process and fosters students' confidence in their learning. The results of this study indicate that students feel more confident in completing tasks effectively. The use of VR has a significant impact on increasing students' confidence in learning [76]. This confidence boosts students' motivation to continue learning when using VR. The findings of this study contribute to providing recommendations to teachers and decision-makers in the field of education to implement VR in enhancing students' self-efficacy in learning rotational dynamics.

Researchers have revealed that the use of VR has a moderate effect on physics learning [69]. Other findings indicate that the effect of VR falls into the large category [77]. However, this study found that the implementation of VR has a huge effect category on improving students' creative thinking skills and self-efficacy. In addition, the multisensory experience offered by VR, which includes visual, auditory, and tactile stimuli, can improve emotional engagement and inspiration in creative thinking [78]. These findings confirm that VR makes a significant contribution to supporting the learning process, particularly in the topic of rotational dynamics in physics. The continuous advancements in VR technology greatly contribute to improving students' self-efficacy, supporting learning, and fostering students' critical thinking skills in physics education [79].

The use of VR in learning significantly influences the improvement of students' creative thinking skills and self-efficacy. Activities within the VR environment allow students to directly interact with objects, explore, and repeat experiments, thereby boosting their confidence in problem-solving [80]. VR learning media holds great potential to foster self-efficacy through engaging, interactive, and immersive presentations [81]. It also provides a learning experience that simplifies the understanding of complex concepts by visualizing real-world phenomena in a straightforward manner [82]. This study's findings indicate that VR-based learning is more effective than slide presentations, especially in encouraging students' exploration of creative ideas based on observed phenomena [83].

VR enables students to modify objects within the virtual environment, explore problem-solving approaches, increase curiosity, and generate new ideas [84]. Furthermore, this technology is cost- and time-efficient, allowing virtual experiments to be conducted repeatedly without resource limitations [85, 86]. Nevertheless, the initial budgeting for VR software and hardware requires a higher investment. In this study, the cost of hardware, including VR headsets, supporting computers, and other additional equipment, amounts to USD 1,500, while the software costs USD 650, resulting in a total initial investment of USD 2,150. Although VR involves higher costs, its benefits in improving students' creative thinking skills and self-efficacy are more substantial compared to Slide Presentation. Based on this analysis, it can be concluded that VR has significant potential to improve students' creative thinking; however, it comes at a higher cost than Slide Presentation. Therefore, for educational institutions with budget constraints, VR implementation can be carried out selectively for specific instructional materials that require deeper exploration.

By using VR, students can grasp phenomena that are challenging to explain using conventional methods and solve problems more quickly [87, 88]. As a novel finding, this research demonstrates that VR improves conceptual understanding and improves students' creative thinking skills and self-efficacy in learning physics. The findings of this study indicate that implementing VR in learning is recommended for teachers and educational institutions as a technological innovation to support the learning process. However, this study has limitations, particularly in its analysis, which is based on a relatively small sample size. Further research is suggested to explore moderator variables, latent variables, confounding factors, as well as the impact of VR use on students' health and 21st-century skills on a broader scale.

VI. Conclusion

Learning using VR has proven to have a better impact compared to learning through slide presentations, especially in complex topics such as rotational dynamics. The research results show that students who learn with VR exhibit better creative thinking skills. Additionally, VR-based learning has a significant influence on improving students' self-efficacy. Compared to learning with slide presentations, students using VR feel more confident when facing learning challenges. The implementation of VR demonstrates a very large effect size in enhancing students' creative thinking abilities and self-efficacy, indicating that VR has a significant impact in supporting the development of creative thinking skills and self-efficacy, especially in subjects that require in-depth understanding, such as rotational dynamics. With VR-based learning, concepts in rotational dynamics, such as rotational motion and the relationship between force and torque, can be visualized more clearly and engagingly, allowing students to grasp these concepts more easily.

However, this study has several limitations, including the fact that VR activities were limited to individual learning in virtual environments, which did not account for social or collaborative interactions among students. Furthermore, the relatively small sample size limits the generalizability of the research findings. Future research should explore the relationship between VR-based learning and other variables, such as student interest, learning motivation, and other 21st-century skills. Researchers are also advised to broaden the analysis of overall interactions between users in virtual environments and to increase the sample size in order to gain a more comprehensive understanding of the potential and limitations of VR in education.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Y. came up with a research idea, developed it and wrote an article; F.M., M.D., and F.N. processed research data and wrote articles; D.H., N.S., and S.R.H. played a role in developing virtual reality; all authors had approved the final version.

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