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Student's Readiness in Using Virtual Reality for Physics Learning

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Article abstract

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Abstract

Virtual Reality (VR) technology in learning activities assists in visualizing abstract phenomena of physics concepts. This technology supports the delivery of effective and meaningful learning experiences. The main objectives of this study, therefore, are to analyze the level of students' readiness to use VR technology in higher education, and to analyze the factors most affecting students' readiness to use VR technology in physics learning. The research employed a questionnaire-survey method with 127 physics education students from a university in Indonesia, distributed based on age, gender, study level, geographical background, and family economic status. Data collection uses a Likert-scale questionnaire containing ten factors of student readiness for using VR. Data analysis techniques included percentages, the Pearson Product Moment Correlation, and multiple regression. The results of this study indicate that the level of students' readiness to use VR technology falls into the intermediate category (71%). The two factors most influencing students' readiness, that were identified from the correlation coefficients, are the availability of access to VR devices and basic technical skills in operating VR technology. Students' readiness to use technology in learning serves as the basis for determining which steps should be prioritized to prepare for technology-enhanced learning, ensuring that the technology positively impacts the learning quality.

Introduction

The learning process involves interaction between students and various parties, such as educators and learning resources in the learning environment (Anderson et al., 2020). Effectively achieving the learning objectives reflects the practical nature of the learning activities, which depend on how the teacher manages the learning process inside and outside of the classroom. Physics learning aims to facilitate students' understanding of physics concepts and principles (Shishigu et al., 2018). It provides a foundation for developing knowledge, skills, and confidence, enabling students to apply all aspects learned during the learning process in their daily lives.

Physics learning emphasizes learning objectives that lead to the comprehension of physics concepts (Sahin, 2010). With the significant advancement of technology, physics learning has become more accessible through technology-based, innovative, and creative learning media (Rizal, 2023). Effective physics education heavily relies on instructional media, which significantly impact learning activities. The instructional media, in the form of teaching aids, serve as a medium of transmission, or sources of information, from the learning source to the recipient. These tools can represent the teacher in presenting learning materials to students (Rohman et al., 2021). It can also stimulate new desires and interests, create motivation, encourage teaching activities, and uplift the students' learning psychology (Lee, 2014). Rizal et al. (2024) stated that the benefits of instructional media include making the learning process more engaging, thereby increasing students' motivation to learn, clarifying the learning material so that students can easily understand it, making the learning process more varied, and involving students in various activities during the learning process, such as observation, practice, and demonstration. When used effectively in various forms, instructional media can help reduce the visual perception difficulties experienced by students (Esgin & Gurbulak, 2016). One of the potent mediums of instruction in the technologically emersed contemporary world that we presently live in is the VR.

Virtual Reality is an alternative medium consisting of a three-dimensional version of the natural world with additional multimedia components, such as virtual objects and sounds. It provides a 360° view, allowing users to look in all directions, by using specific computer components, such as a headset with an internal screen and sensor gloves (Asad et al., 2021). The use of VR technology enables users to experience a different digital world. They can even interact virtually with various objects in VR. This technology can create environments similar to the real world, or a fantastical world, that offers impossible experiences in conventional physical reality. Three-dimensional environments are simulated by VR headsets or multi-projection environments that combine realistic images and sounds (Smutny, 2022). This technology began to be developed in the 1960s, using the concept of the illusion of reality with 3D moving images. The Sensorama simulator stimulates four senses: vision, hearing, touch, and smell (Sun et al., 2019).

Initially, VR technology was widely used in the entertainment industry, but as it developed, various other fields began utilizing it according to their needs (Yildirim et al., 2018). Virtual Reality has also been extensively used in multiple subjects or courses at different learning levels, including elementary (Chang et al., 2020), secondary (Markowitz et al., 2018), and higher education (Dubovi et al., 2017). This tool has also been helpful in research, with content related to biology (plant-cell physiology and anatomy), medicine (bone-surgery simulations), engineering, geography (climate change), astronomy, and nursing (Dunnagan et al., 2020; Šašinka et al., 2019; Vergara et al., 2017).

Virtual Reality is emerging as an increasingly important educational tool, especially in the STEM (Science, Technology, Engineering, and Mathematics) fields. This technology allows students to experience hands-on and interactive learning, creating a more immersive experience than conventional methods. In physics, VR plays a huge role, as it allows visualization and interaction with abstract concepts that are difficult to understand through traditional media. For example, students can visualize and interact with phenomena, such as electromagnetic fields, Newton's laws of motion, or the principles of thermodynamics in three-dimensional space, enriching their understanding (Rivas, 2020). In this way, students not only read or hear about physics concepts, but can experience them directly, such as conducting virtual experiments that would be impossible in the real world (Freina & Ott, 2015). This allows them to understand more complex material in a more intuitive and engaging way and increases their motivation to learn. In addition, VR in physics education opens opportunities for interactive and immersive experiential learning approaches, which increase student engagement and retention of information (Bailenson, 2018). As this technology advances, its potential in education continues to grow, making it a highly effective tool in STEM learning.

Literature Review

The widespread use of VR in learning activities, at various learning levels and subject matters, is due to its benefits and advantages offered to students during the learning process (Mikropoulos & Natsis, 2011). It provides realistic experiences at a low cost, is easy to apply, can be repeated, and is not bound by space and time (Guan et al., 2022). This technology offers a different learning experience for students, with tools that can visualize objects and allow users to interact with them, thus facilitating an enhanced understanding of the material being presented (Ferrell et al., 2019). Virtual Reality aids in demonstrating accurate functions or activities, enabling students to recognize and explore abstract or difficult-to-observe knowledge in a risk-free environment (Bourhim & Cherkaoui, 2020; Morélot et al., 2021). The various content developed in VR technology, combined with the technical organization of learning activities, helps teachers or lecturers facilitate students in achieving learning objectives according to their respective fields (Luo et al., 2021). A study by Alhalabi (2016) showed that engineering students who learned using VR media (in three different modes) had better learning outcomes than those who did not use it. The learning outcomes tested in this study included knowledge, cognitive skills, mathematical skills, and the ability to understand graphs and diagrams. The difference in learning outcomes between students using VR and those who did not ranged from 8% to 30%.

Virtual Reality technology has been found to have a psychologically positive impact on students' learning activities, including increased internal motivation, interest, satisfaction, engagement, or experience. A study by Ferrell et al. (2019) showed increases in students' motivation to learn, as well as their curiosity about the material being discussed. After learning about molecular structure using VR, students evaluated the learning experience through a questionnaire, and reported a 50-80% increase in learning motivation, along with a more profound curiosity about the subject matter. This teaching tool promotes emotional experiences in the form of empathy (Bertrand et al., 2018), as described by Schutte & Stilinović (2017), who found that participants exploring the VR documentary experience of a 12-year-old girl in a refugee camp showed greater empathy, as compared to those who watched without VR. Riva et al. (2012) showed that VR experiences have a positive potential for motivation and emotions. Arnone et al.

(2011) proposed that these simulations provide experiences that can trigger curiosity, consisting of a desire for novelty. Reports from VR users provided some support through feedback from museum visitors. They rated these events very positively and stated that their experiences riding the elevator into a tunnel were new and unique, unlike anything that they had experienced before (Jung et al., 2016).

Integrating VR technology into learning activities is highly promising for innovative learning with contextual and interactive approaches. This new method increases students' interest in acquiring knowledge differently, by engaging sensory knowledge (Pan et al., 2006). Other research areas include the role of VR in developing learning motivation, attitudes, and cognitive load (Chen et al., 2020). It can promote affective, behavioural, and cognitive engagement; offer live simulations that cannot be done in the real world; concretize abstract ideas and concepts; expand the sense of presence; and enable active interaction with the content, therefore, enhancing knowledge acquisition and transfer (Saredakis et al., 2020).

The use of VR in physics learning provides several advantages, because it effectively captures students' attention and encourages active learning through immersive and interactive experiences. This tool has the potential to create a more realistic and engaging learning environment. When students interact with the virtual world, they do not just passively receive information, but are also directly involved in the learning process, which increases their attention (Slater & Wilbur, 1997). This experience can increase students' intrinsic motivation, because they feel more involved in learning, improving their concentration and memory of the material being taught (Jayakrishnan et al., 2023). In addition, VR encourages active learning by allowing students to explore and test the concepts that they are learning in a safe and controlled context. For example, in physics, students can conduct virtual experiments, change variables, and directly observe the results, without the physical limitations of real-world experiments. Virtual Reality in physics learning encourages them to think critically and reflectively about what is happening and allows them to learn through direct experience (Rizzo & Koenig, 2017). This VR-based learning, which emphasizes experimentation, exploration, and problem-solving, helps students to develop analytical and higher-order thinking skills. It also encourages active learning by enhancing collaborative elements. In some VR applications, students can work in groups to solve problems or explore specific scenarios, strengthening their communication and collaboration skills (Caprara & Caprara, 2022). Thus, VR helps students understand the material better and allows them to engage socially in the learning process.

Virtual Reality has the incredible ability to visualize complex and abstract physics concepts, such as electromagnetism and quantum mechanics, in impossible ways. In the context of physics education, VR offers a three-dimensional (3D) environment that allows students to see and interact with phenomena that can usually only be described through mathematical equations or two-dimensional representations. This apparatus changes how students understand and interact with complex concepts, making them easier to understand and more engaging. The concept of electric and magnetic fields is often difficult to grasp, because of its invisible nature. With VR, students can visualize electromagnetic fields in 3D, moving and interacting with charges, and see how forces act between charged particles. For example, using VR, students can observe how magnetic fields affect the movement of charged particles, or how electromagnetic waves interact with objects in three-dimensional space (Dede, 2009). Students can be inside the field, providing a hands-on experience that two-dimensional simulations, or conventional physical experiments, cannot provide. Concepts in quantum mechanics, such as superposition and entanglement, are notoriously difficult to visualize, because these phenomena occur on a microscopic scale and cannot be directly observed. Virtual Reality allows students to visualize and interact with subatomic particles in 3D space, observing how they can exist in multiple states simultaneously (superposition), or how two particles can instantly connect, despite being separated by a significant distance (entanglement). For example, VR can simulate experiments, such as particle-wave interference, which shows how particles can act like waves under certain conditions, providing a clear picture of the phenomenon (Mufit et al., 2024). Using VR, abstract and complex concepts in physics become more concrete and understandable, because students can visualize the principles in three dimensions and experience them firsthand. This technology not only enhances understanding, but also makes learning more engaging and meaningful

Virtual Reality in physics learning offers several benefits, particularly in overcoming the physical limitations and costs of dangerous, expensive, or inaccessible real-world experiments. This technology allows experiments to be conducted in a safe and accessible virtual world, creating a more interactive and immersive learning experience. Many physics experiments involve hazardous conditions, such as working with toxic chemicals, high-voltage electricity, or radiation. Virtual Reality allows these experiments to be simulated without risk to participants. For example, in an experiment on electromagnetic fields, students can manipulate electric currents and see how they interact with magnetic fields, observing their effects on objects, without the need to work with dangerous equipment (Franklin & Ryder, 2019).

Another example is nuclear experiments, such as fission or fusion reactions, which usually require tight control of radioactive materials. These can be simulated in VR, giving students a better understanding of the theory and mechanisms involved (Šiđanin et al., 2020). Virtual Reality in physics learning allows experiments to be conducted anywhere, without expensive physical equipment or specialized laboratories. It opens access to physics learning for a broader range of students, especially in areas lacking laboratory facilities. Students from various backgrounds and locations can access physics experiments that are usually only available at universities or research centres, by using simple VR devices at home or in the classroom (Dunleavy et al., 2009). The costs of experiments involving expensive physical equipment, such as particle accelerators or space experiments, can be reduced or even eliminated.

Virtual Reality can help students understand spatial relationships and physical phenomena through immersive and interactive experiences. One of the biggest challenges in teaching physics is conveying concepts that involve the interaction of objects in three-dimensional space, especially those that are difficult to imagine or visualize through two-dimensional media, such as textbooks or static images. With VR, students can be in a simulation to observe, manipulate, and explore physical phenomena directly in a virtual environment. This helps them to better understand spatial relationships, forces, and object interaction (Durukan et al., 2020), including the motion of objects, the forces acting on them, and the direction of the forces in three-dimensional space, which is difficult to achieve with traditional media (Kim et al., 2001). Other topics that VR allows students to explore are relativity, quantum physics phenomena, as well as concepts related to gravity, waves, and energy (Tarng & Pei, 2023). Virtual Reality also facilitates experiential learning, which is particularly effective for studying physics phenomena. By being directly immersed in this subject area, in a virtual simulation, students can gain a more comprehensive understanding of physics phenomena and connect theory to practice more efficiently. For example, they can experience gravity or high speed in realistic situations, without high risk or expense. In an orbital motion simulation, students can feel the movement of planets around the sun, seeing the spatial relationships between planets in the solar system.

Virtual Reality can also help students conduct experiments to distinguish between uniform linear motion and uniformly accelerated linear motion. For example, if a resultant force is reduced, the object will experience a decrease in speed (Kaufmann & Meyer, 2009), and this can be seen by experimenting with the data on objects' position, time, and velocity at several points in digital simulations. The data can be analyzed to distinguish the characteristics of the two motions, which can be identified from the differences in the object's velocity conditions in the two object movements (Rivas et al., 2017). Another example involves the visualization of invisible magnetic fields into visible ones (concepts of force, field, and interaction). In this way, students see magnetic fields as field lines moving around a magnet. This simulation shows the direction of the field from the north pole to the south pole, and its intensity based on the distance from the magnet (Shinde & Sarma, 2024). With VR, students can understand that the magnetic field is stronger near the poles and weakens as it moves away. They can even manipulate parameters, such as the magnet's strength and position, or insert ferromagnetic materials to see their effects on the field lines. This interaction helps students understand how the magnetic field is affected by the presence of certain materials, or the geometric arrangement of the field.

Virtual Reality has great potential to explain abstract quantum physics concepts more visually and intuitively, such as particle-wave duality, atomic models, probabilistic phenomena, interference and diffraction (properties of waves), as well as the production of interference patterns from particles, such as electrons. According to Tarng and Pei (2023), hands-on experience with VR simulations helps users to understand how electrons behave like waves in the double-slit experiment, which is difficult to imagine in three-dimensional space without visual aids. Atomic models are also better explained by using this media, because it depicts the positions of electrons that are not in fixed orbits, but in probability clouds. This spatial representation of these orbitals and electron distributions, can be viewed in these atomic models from different angles, making it easier to understand concepts, such as orbitals and electron position constraints (Nersesian et al., 2019). In astronomy and cosmology, students can travel and explore space in an immersive and interactive way, so that they can explore the solar system, galaxies, and cosmic objects as if they were there in person. These virtual visits to the planets, stars, asteroids, nebulae, and even black holes can be seen at a realistic scale (Kersting et al., 2024) and this makes it easier to understand the structure and characteristics of celestial bodies, such as Saturn's rings or the gravitational field around a neutron star (Ferrand, 2023). By changing the user's perspective, VR can compress or enlarge the scale to explain difficult-to-understand concepts (Atta et al., 2022).

Hardware and software are needed to support the advantages of Virtual Reality in learning. Hardware for this typically consists of a VR headset, a high-spec computer, and additional input devices, such as motion controllers (Anthes et al., 2016). VR headsets, such as the Oculus Rift or HTC Vive, offer immersive 3D visualization, but require a computer with advanced graphics specifications to support complex, visual, and interactive data processing. At this writing, computer systems generally require a minimum specification of an Intel i5 processor or better, a minimum of 8GB of RAM, and a high-end graphics card, such as an NVIDIA GTX 1060 or better. Motion controllers, like joysticks, are also needed to allow user interaction with the simulation in the VR environment (Freina & Ott, 2015). On the software side, this educational technology requires a dedicated VR platform or appropriate simulation, such as Unity or Unreal Engine, that supports VR application development and interactive modelling (Mikropoulos & Natsis, 2011). In addition, this software requires additional coding to ensure that the simulation runs according to the underlying laws of physics. Specific VR educational applications, (i.e. Google Expeditions and Labster), offer science simulations, but may not always support quantum physics in depth. In addition, educators or students require basic hardware and software skills, so that learning activities can run effectively. Therefore, adequate training is needed to ensure an understanding of how to use VR devices technically and pedagogically. Hands-on practice sessions allow users to build confidence when working with the tool. Studies show that practice-based training improves technical skills and reduces barriers to using new technologies (Shepelev et al., 2023).

With the advent of artificial intelligence (AI), haptic feedback, and increasingly high-resolution VR, there is an excellent opportunity to enhance physics learning through VR. This combination paves the way for fully immersive learning scenarios. For example, students can enter a simulated environment to experiment with complex physics phenomena in real-time, such as simulating molecular collisions or fluid flow. Artificial Intelligence can be used to create more personalized and adaptive physics learning. These systems can analyze user interaction data to provide real-time feedback, adjust the difficulty level, or provide additional explanations based on student errors (Mahligawati et al., 2023). Haptic feedback allows users to experience physical interactions with the virtual environment, such as forces, vibrations, or pressure. In physics learning, this technology will enable students to truly feel how forces act, such as pulling a spring or centrifugal force on an object moving in a circle (Burdea & Burdea, 1999; Richard et al., 2021). Abstract concepts can be more thoroughly understood through direct experience. The high resolution of VR devices provides more explicit and more realistic visualizations. In physics learning, it is essential to understand the minute details of phenomena, such as magnetic fields or light interference patterns. Sharp, distortion-free visualizations facilitate conceptual understanding and allow exploration of microscopic to astronomical environments (Slater & Sanchez-Vives, 2016).

To optimize the use of VR in physics learning activities, institutions need to support the increase of wider accessibility by considering cost constraints, infrastructure limitations, and the availability of relevant content. One of the main barriers to the use of VR is the price of these devices. Technological innovation is needed to reduce the cost of VR hardware and software. The development of cloud-based solutions or simpler devices, such as mobile VR that is compatible with smartphones, can also be an alternative to reduce costs (Freina & Ott, 2015; Pirker et al., 2022). In addition, educational institutions can collaborate with technology companies to provide VR devices at affordable prices, or through grant programs to reduce the costs involved. This partnership can be done by device rental or subsidy programs (Merchant et al., 2014). Infrastructure limitations also need to be addressed, since a stable internet network in schools and special classrooms designed to support the use of VR, including adequate open space, is essential (Pantelidis, 2010). The institution should collaborate with educational and research institutions, or developers, to overcome limited VR content. For example, platforms such as Labster provide virtual laboratory simulations that support STEM learning at a lower cost than physical laboratories. Studies have shown that effective VR-based content development requires the involvement of researchers, educators, and technology developers to create pedagogically and technically relevant materials. This collaborative approach can increase the effectiveness of VR in supporting learning, especially in science and engineering (Cromley et al., 2023). In addition, the creation of open-source VR content allows wider access to educational institutions with limited budgets, provided that the VR content is relevant to their educational needs (Wu et al., 2013).

Theoretical Framework

It is essential to consider the readiness of students who will operate VR to maximize potential technology in physics learning. The theory of constructivism provides a strong framework for understanding students' readiness to use this media for learning physics. By emphasizing active learning, social interaction, reflection, and adaptation to technology, this theory helps explain how students can be more prepared to utilize VR as an effective learning tool. Constructivism argues that students build their knowledge through experience and interaction with their environment. Virtual Reality offers an interactive and immersive learning experience, where students can simulate physics concepts in realistic contexts. This can enhance student engagement and make them more prepared to learn (Moore & Piaget, 1971). Constructivism also highlights the importance of the social context in learning. Students can collaborate in a VR environment, share knowledge, and support each other in understanding physics concepts. Student readiness to use VR may be influenced by this social interaction. In a constructivist approach, students are encouraged to reflect on their experiences. Virtual Reality allows students to experience physics situations firsthand and then reflect on them, which can help them realize the strengths and weaknesses of their own understanding (Vygotsky, 1978). The theory of constructivism also emphasizes the importance of students' adaptation to new tools and technologies. VR, as a new learning tool, requires students to adjust their learning methods. Those with prior experience with technology tend to be more ready to use VR in learning (Malraison & Papert, 1981).

The theory of self-efficacy provides a theoretical backing for this study. It emphasizes the importance of readiness to use VR technology in supporting success in learning. Self-efficacy refers to an individual's belief in one's ability to complete specific tasks (Bandura et al., 1999). In the context of VR usage, students who possess this, regarding using this tool, are more likely to feel ready and confident to engage in VR-based learning. Self-efficacy influences student motivation, and those who are confident in their ability to use it will be more interested in participating in physics learning. They tend to put in more effort and are less likely to give up when faced with challenges (Zimmerman, 2000). Self-efficacy can be developed through the positive experiences that students have, which increases their confidence in their ability to use it (Bandura 1986). In addition, self-efficacy is also based on students' beliefs in the usefulness of the technology that they are using for learning. If they believe that VR will improve their understanding of physics, they are more likely to feel ready to use it (Davis, 1989).

It is essential to consider the readiness of students who will operate VR, so that the potential benefits of this technology in physics learning are maximized. This is considered with several arguments, including its potential to optimize students' learning experiences. Learning activities can be prepared following the learning incidents students have already had, so that there is improvement in their learning outcomes and engagement (Radianti et al., 2020). Student readiness also plays a role in reducing technical and psychological barriers during learning. Assessing student readiness can help to identify potential technical and psychological problems during learning activities, and teachers should be prepared, so that these issues can be addressed (Cheng et al., 2015). In addition, this can help teachers design curricula and learning materials that effectively utilize VR, making the content relevant and beneficial for achieving the learning objectives (Jensen & Konradsen, 2018). Merchant et al. (2014) revealed that student readiness affects their satisfaction and motivation with using VR in learning. If students' readiness does not meet expectations, it can be a basis for equipping them with the basic skills needed to use technology in learning (Freina & Ott, 2015).

Moreover, lack of readiness to utilize technology can lead to several disadvantages to student learning. Educational activities may be disrupted (Selwyn, 2011), students may lose the opportunity to engage in active and interactive learning offered by technology (Hattie & Timperley, 2007), and it may exacerbate the skill and ability gaps among students, including academic and social disparities (Sánchez-Díaz et al., 2021). Furthermore, students' unpreparedness in using technology in learning may result in difficulties in understanding and completing tasks related to the technology, ultimately negatively impacting their academic performance (Maryani et al., 2023). More seriously, Venkatesh (2003) indicates that students who are not ready to use technology may feel frustrated and stressed when facing technical problems or difficulties in usage, leading to reluctance to participate in learning.

Considering several factors that can serve as the basis for developing VR relevant to the material and student needs can assess the readiness of students. This readiness can be evaluated from various vantage points, including the availability of hardware and devices for VR technology, supporting infrastructure in the form of internet network access (Dizavandi & Heydari, 2022), the support of the learning environment from both teachers and learning institutions (Kavanagh et al., 2017), basic technical skills in operating VR technology (Radianti et al., 2020), students' basic knowledge of how VR technology works and its benefits in learning (Jensen & Konradsen, 2018), motivation and positive attitudes towards technology (Lee et al., 2010), experience in using VR technology (Pantelidis, 2010), availability of training and skills development for using VR (Birney & McNamara, 2024), availability of access to VR devices (Nesenbergs et al., 2021), basic technical skills in operating VR technology (Lousã & Lousã, 2023), motivation and positive attitude toward using VR in learning (Fredricks et al., 2004; Lee & Turner, 2018), and to adapt to VR technology (Lampropoulos et al., 2022).

Based on the indicators, this study assessed students' readiness to use VR technology to prepare for physics learning at a university in Tasikmalaya, West Java, Indonesia. This study has two main objectives: to analyze the level of student readiness in using VR technology in university courses, and to analyze the factors that most influence student readiness in using VR technology in physics learning.

Research Questions

This study focused on the profile of students' readiness to use VR in physics learning, which is determined based on some factors that have a significant impact. This investigation was developed from two research questions.

1. What is the student's readiness to use VR in physics learning at the university level?
2. What factors influence students' readiness to use VR in physics learning at the university level?

Method

A descriptive research design using a survey method was employed to achieve the objectives of this study. This method collects respondents' opinions, or specific characteristics, through questionnaires or interviews (Groves et al., 2011). Generally, it aims to identify trends, patterns, and relationships within a particular population (Biffignandi & Bethlehem, 2021). The population in this study consisted of students majoring in physics education at a public university in Tasikmalaya, West Java, Indonesia. A stratified sampling technique was used to obtain data representative of the population, specifically students who would be participating in the physics instructional media course. The sample consisted of first- and second-year physics education students in the 2023/2024 academic year, totaling 127 students, distributed by age, gender, geographic background, and economic levels.

The instrument used in this study was a five-point, Likert-scale questionnaire, named fivepoint VR Readiness Questionnaire (VRRQ). It covered several indicators of student readiness when using VR, as well as students' responses to factors influencing their readiness to use the technology. This instrument contained five respondent-response options; namely, strongly disagree, disagree, neutral, agree, and strongly agree. The questionnaire consisted of two primary sections: demographic questions and factors influencing readiness to use VR. The demographics included the year of entry, age, gender, geographic location of residence, high school background, and parents' economic status. The factors influencing readiness to use VR included three questions for each factor, such as the availability of hardware and devices for VR technology, supporting infrastructure in the form of internet network access, the support of the learning environment from both teachers and learning institutions, basic technical skills in operating VR technology, students' basic knowledge of how VR technology works and its benefits in learning, motivation and positive attitude towards technology, and experience with using VR technology. Experts have validated this questionnaire, and the results of empirical field tests show a high reliability ($\alpha = 0.84$) (Tavakol & Dennick, 2011; Vaske et al., 2017).

To gather data on students' readiness to use VR, the digital instrument was distributed online using Google Forms via a link in WhatsApp. This method allowed respondents to complete the questionnaire at any time and place. It also offered practical and cost-effective means of collecting information (Guterbock & Marcopulos, 2019), and students could use either computers or smartphones. To ensure the accuracy of information without any intervention, researchers did not ask for specific identifying information (anonymous) and clarified in the questionnaire that their responses would not affect their academic performance during the course (Rizal et al., 2020).

The response scores were calculated as a percentage average, which was categorized into three readiness levels: "low" for percentages below 45, "intermediate" for percentages between 45-90, and "high" for percentages above 90 (Dehghan et al., 2022). Two statistical tests were conducted using specialized software to assess the impact of each factor on student readiness to use VR. The first step involved a multiple correlation test to determine the simultaneous correlation of all aspects with student readiness. The second step comprised a multiple regression analysis to assess the linear relationship between a combination of 10 predictor variables and student readiness.

Results and Discussion

Respondent demographics

All respondents involved in the study were classified based on six demographic categories, including academic level, gender, age, geographic origin, and parental economic status. The demographic grouping of the participants can be seen in Table 1.

Table 1. Distribution of respondent demographics.

No	Variable	Frequency	%
1	Grade		
	1st year	53	42%
	2nd year	74	58%
2	Gender		
	Male	18	14%
	Female	109	86%
3	Age		
	19 years	23	18%

No	Variable	Frequency	%
	20 years	76	60%
	21 years	23	18%
	22 years	5	4%
4	Geography		
	Beach	4	3%
	Village	61	48%
	Highlands	7	6%
	Suburban	13	10%
	Urban	41	32%
5	Economic level		
	Low	55	43%
	Middle	67	53%
	High	5	4%

The participants involved in this study were predominantly second-year students, as the number of students in this group was more significant than that of first-year students. In terms of gender, the participants were predominantly female, with a percentage of 86%. The number of female students in physics education is significantly higher, and this trend is reflected in the faculty of education and teacher training, where female students far outnumber their male counterparts. Regarding age, most of the students participating in this study were 20 years old, since the group included both first- and second-year students. The majority of respondents came from rural areas, followed by those from urban areas. The students involved in this study were from various regions around Tasikmalaya. Economically, the respondents mostly came from middle- and low-income families.

Students' readiness level for using VR in learning

Analyzing students' readiness levels was a key focus of this research. This readiness level was assessed based on ten indicators of technology usage readiness as outlined in the developed instrument. The summary of the participants' responses is described through readiness percentages, as shown in Table 2.

Table 2. Students' readiness level for using VR in physics learning.

No	Readiness Indicators	Percentage	Category
1	Learning environment support for using VR	83%	Intermediate
2	Availability of supporting infrastructure for VR technology	77%	Intermediate
3	Availability of training and skill development for using VR	73%	Intermediate
4	Availability of access to VR devices	69%	Intermediate
5	Basic knowledge of using VR in learning	63%	Intermediate

No	Readiness Indicators	Percentage	Category
6	Basic technical skills for operating VR technology	62%	Intermediate
7	Motivation and positive attitude toward using VR in learning	80%	Intermediate
8	Experience in using VR technology	61%	Intermediate
9	Ability to adapt to VR technology	72%	Intermediate
10	Creativity in using VR technology	74%	Intermediate
	Mean	71%	Intermediate

Based on the data presented in Table 2, the readiness level of physics-education students to use VR technology in learning is 71%, which places it in the "intermediate" category. The factor with the highest percentage, at 83%, also falls within the intermediate category, and pertains to institutional support in providing VR devices. Conversely, the factor with the lowest percentage is the students' experience in using the technology.

Institutional support in providing VR devices in this study included institutional and instructor support in supplying the equipment, usage guidelines, and dedicated spaces for using VR technology. The dean's office had provided a special room, referred to as the Smart Class, to be used for learning activities with the latest technology. For the technological support available in the Smart Class, the institution has provided several VR devices that can be used by both students and lecturers in their teaching and learning activities.

Particularly in providing VR devices, institutional support is a crucial factor influencing students' readiness to use this technology in the learning process. Learning institutions that supply high-quality and adequately available VR devices not only enhance the accessibility of this technology but also strengthen students' readiness to utilize VR effectively (Adelana et al., 2023). By providing these learning tools, institutions ensure that all students have equal access to this technology. Research by Jensen and Konradsen (2018) suggests that equitable access to VR devices allows students to practice and become accustomed to this media, thereby increasing their readiness to use it in a learning context.

Without institutional support, students might struggle to independently access VR devices, due to their high cost, which could hinder the adoption of the technology (Ma et al., 2023). Furthermore, the availability of VR devices in learning institutions also facilitates an ample and more sustainable integration of this technology into the curriculum. When institutions actively support the use of VR by providing the necessary devices, instructors are more likely to incorporate it into their teaching designs, which enriches the learning experience for students. Radianti et al. (2020) emphasize that institutional, solid support in procuring learning technology, including VR, is essential to promoting the adoption and comprehensive utilization of technology in the learning process.

Institutional support in providing VR devices also creates an innovative learning environment that encourages students to accept new technologies. Surroundings that are equipped with VR technology not only prepares students for current learning, but also for future challenges in a technologically driven workforce. Learning environments supported by advanced technology, like VR, can enhance students' motivation and readiness to learn, because they feel that the institution is holistically supporting their development (Merchant et al., 2014).

On the other hand, the factor with the lowest percentage, experience in using VR technology, might be attributed to the limited availability of devices in previous learning institutions. Many academic buildings at the secondary level do not provide adequate access to VR devices, due to their high costs and complex technical requirements (Fransson et al., 2020). The geographic location of students' residences also significantly impacts their experiences. Schools in urban areas may have better access compared to those in rural areas. The respondents in this study were predominantly from rural areas and attended schools where the availability of VR technology is likely still low. The low participation rate in using VR technology among students can also be attributed to factors such as lack of parental support, potential health risks to users, and limited time available for using VR (Alalwan et al., 2020).

Factor analysis affecting students' readiness in using VR as a learning tool

To analyze the impact of factors affecting students' readiness in using VR technology, a correlation analysis of 10 factors related to student readiness was conducted. The correlation test was performed first, partially to ensure that the independent variables had a qualifying correlation with one another. The results of the partial correlation among the independent variables are presented in Table 3.

Table 3. Partial correlation results among independent variables.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_8	X_{10}
X_1	1,000	0,517	0,663	0,473	0,425	0,425	0,507	0,347	0,507	0,525
X_2		1,000	0,607	0,619	0,575	0,575	0,575	0,453	0,563	0,598
X_3			1,000	0,767	0,686	0,686	0,691	0,600	0,654	0,746
X_4				1,000	0,702	0,702	0,615	0,687	0,635	0,716
X_5					1,000	0,876	0,594	0,778	0,739	0,737
X_6						1,000	0,594	0,778	0,739	0,737
X_7							1,000	0,496	0,747	0,717
X_8								1,000	0,618	0,722
X_9									1,000	0,805
X_{10}										1,000

Information

X_1 = Learning environment support

X_2 = Availability of infrastructure

X_3 = Availability of infrastructure

X_4 = Access to VR devices

X_5 = Basic knowledge of VR

X_6 = Basic technical skill

X_7 = Motivation and positive attitude

X_8 = Experience in using VR

X_9 = Ability to adapt VR

X_{10} = Creativity in using VR

Based on the information in Table 3, the highest correlation coefficient between the independent variables is 0.805. This condition still meets the criteria for determining the correlation among multiple independent variables affecting the dependent variable, noting that the correlation coefficient between independent variables must be less than 0.9 (Tabachnick & Fidell, 2019).

The researcher also aimed to assess the accuracy of the ten identified factors for determining students' readiness to use VR. The statistical analysis revealed that the adjusted R^2 value for these ten variables is 0.932, meaning that together, these factors account for 93.2% of the student's readiness. The remaining 6.8% is influenced by other factors that were not examined in this study. Cohen (1992) explains that the impact of a variable can be categorized into three levels: small, medium, and large, with corresponding adjusted R^2 values of 0.0196, 0.1304, and 0.2592, respectively. Therefore, the adjusted R^2 value found in this study is significantly higher than 0.2592, indicating that these ten factors have a highly significant impact on students' readiness to use VR.

It is necessary to analyze which factors are the most urgent and have the most significant impact to prioritize the fundamental needs in supporting VR readiness. Hence, the researcher conducted multiple regression analyses to determine the significance of each factor's contribution. The results of the regression analysis are presented in Table 4.

Table 4. Results of multiple regression analysis for each factor.

No	Factors	Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	Learning environment support	0.971	0.102	0.115
2	Availability of infrastructure	1.012	0.105	0.118
3	Availability of training	0.933	0.147	0.112
4	Access to VR devices	1.193	0.116	0.161
5	Basic knowledge of VR	0.983	0.115	0.125
6	Basic technical skill	1.664	0.126	0.226
7	Motivation and positive attitude	1.192	0.141	0.123
8	Experience in using VR	1.031	0.115	0.138
9	Ability to adapt VR	1.000	0.147	0.117
10	Creativity in using VR	0.944	0.164	0.106
	Constant	0.027	0.391	

The information in Table 4 shows that the two most dominant variables in determining students' readiness to use VR technology are access to VR devices and basic technical skills. Students who have easy access to VR devices and possess skills in operating VR technology will be more prepared to utilize VR technology in learning. Access to VR devices allows students to interact with the technology more frequently and potentially increases their comfort and confidence in using it (Fei et al., 2023). Students with better access to technology tend to be more prepared and responsive to technology-based learning. Regular use of VR also enables students to understand how this technology works and its potential to support the learning process, which ultimately enhances their learning outcomes. Equal access to VR devices facilitates broader application within learning environments. When all students have the same opportunity to access VR, academic institutions can integrate this technology into the curriculum more effectively. The student's readiness is crucial to ensure that all students have a uniform and high-quality learning experience. The practical experiences gained by students through access to VR devices also helps to improve their mental readiness. Students who interact with VR technology more frequently will have higher levels of expertise, enabling them to make the most of this technology in learning (Reeves et al., 2021). These experiences also help students overcome technical barriers that may arise, allowing them to focus on the learning content presented through VR.

Easy access to VR devices permits students to explore various applications and potential uses of this technology in learning. By interacting directly with VR, students can see how this technology visualizes complex concepts, simulates real-life situations, and enhances their engagement with the learning material (Freina & Ott, 2015). A deeper understanding of VR's potential is essential for preparing students to use this technology effectively. Access to VR devices also provides students with opportunities to experiment with new ways of utilizing this technology for learning. They can try various VR applications, explore different virtual environments, and even develop innovative projects that leverage VR. These encounters not only increase their readiness to use VR, but also fosters creativity and critical thinking in applying technology for learning purposes (Tiwari et al., 2023)

Basic technical skills in using VR also have a significant impact on readiness. They enable students to understand how VR devices work, such as how to activate and navigate virtual environments. Without these skills, students may feel frustrated or hindered when trying to use VR, which can disrupt the learning process. Conversely, students with basic technical skills will be better prepared to use the devices efficiently and focus on the learning material (Kumar et al., 2008). Students who already have basic technical skills tend to adapt more easily to new technologies, including VR. They will learn new features more quickly and handle technical issues that may arise. Technology adaptation is important, because VR technology continues to evolve, and the ability to adapt quickly will enhance students' readiness to use this technology in various learning contexts (Kumar et al., 2008; Tiba & Condy, 2021). Basic technical skills help students overcome technical barriers that may occur when using VR, such as issues with device connectivity, understanding software settings, or handling bugs in VR applications. With these skills, students can be more independent in addressing technical problems, making the time spent on learning more optimal (Musyaffi et al., 2023). Students with basic technical skills can utilize VR more effectively for learning. They are not only able to run VR applications but also explore features that can enhance their understanding and engagement with the learning material. These skills enable students to maximize the use of VR as an interactive and immersive learning tool, which can improve their learning outcomes (Maryani et al., 2023).

Conclusion

The level of readiness of students to use VR in physics learning is intermediate. This categorization considers ten factors that theoretically indicate students' readiness. All these indicators fall within the intermediate percentage range, with the highest percentage in the learning environment supporting the use of VR, and the lowest rate in the indicator of experience with VR technology. The difference in the percentage of student-readiness levels for each indicator is a consideration in determining what steps need to be taken to address these weaknesses. Before providing VR lessons, students should be allowed to understand how to use VR devices and gain experience with it through simple training activities. This can boost students' confidence in using these tools and minimize technical issues during lessons, ensuring that the learning activities using this media can be carried out effectively

Statistically, the two most influential factors on students' readiness to use VR in learning are the availability of access to VR devices and basic technical skills in operating VR technology. The availability of access to VR devices that can be used in learning is already adequate, providing positive support for students' readiness to use VR in education. However, basic technical skills in operating this technology still need to be improved. These fundamental skills play a crucial role in ensuring a smooth learning process, so that students can focus more on understanding the material presented this way and are not hindered by confusion in using the VR devices.

Limitation of the study

Although this research provides valuable insights into students' readiness to use VR as a medium for learning physics, there are several limitations that should be noted. First, the sample of this study was limited to several students from one educational institution, so the results may not necessarily be generalized to a wider population. Other factors, such as educational background, access to technology, and the learning environment in other schools, may affect students' readiness levels differently. Second, this study focused more on the technical and psychological readiness of students, but did not explore, in depth, the impact of VR usage on students' learning outcomes in physics. The correlation between students' readiness and the improvement of their understanding of physics concepts through VR still requires further investigation. Therefore, follow-up studies measuring the effectiveness of VR in enhancing academic performance in physics are needed.

Recommendation

Physics learning using VR can improve students' conceptual understanding, learning motivation, and interactive experiences. With its immersive capabilities, VR can help visualize abstract and difficult-to-understand physics phenomena through conventional methods. For example, concepts such as quantum mechanics, electromagnetic fields, or particle dynamics can be illustrated realistically, strengthening the connection between theory and real-world applications. However, implementing VR in physics learning requires thorough preparation from various parties, including students, lecturers, and educational institutions. Factors such as technological literacy, infrastructure availability, learning-module design, and technical support are the main determinants of the success of VR integration. Barriers, such as device costs, user adaptation, and potential health problems, must also be considered to ensure the program's sustainability.

Therefore, based on the research that has been conducted, it is recommended that students and lecturers undergo initial training on the use of VR devices, including how they work and operate, as well as basic troubleshooting. This technology-orientation program can be carried out before VR is implemented in physics learning to ensure that students are more technically and psychologically prepared. In addition, learning modules specifically designed for VR are needed, focusing on physics topics that are difficult to understand conventionally, such as quantum mechanics, electromagnetism, or wave phenomena. These modules should include interactive simulations that utilize VR's immersive capabilities. Further research is also necessary to evaluate the impact of VR use on physics learning outcomes, such as conceptual understanding, learning motivation, and problem-solving skills. The results of this study can help improve VR-based learning methods

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