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The Impact of Virtual Reality on Programming Algorithm Courses on Student Learning Outcomes

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Abstract. The low learning outcomes of students and the limitations of learning media provide opportunities to develop innovations that can increase student engagement. One form of innovative and interactive media that supports student engagement is VR technology. This study aims to determine the impact of VR compared to traditional learning in improving student learning outcomes on programming algorithm materials. The method applied was a quasi-experimental design through pretest and posttest. The population in this study consists of six classes. Through random sampling techniques, class A was selected as the control class with 19 students and class B as the experimental class with 16 students. In the control class, students apply traditional learning, while the experimental class uses VR-based learning. The data was processed with the Wilcoxon test to see the improvement of learning outcomes in each class and the Mann-Whitney test to compare results in both classes. The results of the Wilcoxon test showed a score of sig (2tailed)<0.05 in both classes which showed that traditional learning and learning with VR encouraged improved student learning outcomes. Traditional learning scores increased from 53 to 67, while group scores. Meanwhile, the results of the Mann-Whitney test showed a score of sig (2tailed)<0.05 which means that the effectiveness of VR is better in improving learning outcomes than traditional learning. Therefore, learning with VR effectively improves student learning outcomes on programming algorithm materials. Other researchers can conduct further research to explore and investigate the impact of VR on health and the use of remote learning.

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1. Introduction

In this decade, digital technology has experienced significant growth. This condition is supported by various virtual media that are getting closer to the real environment (Nair et al., 2021; Shi et al., 2023; Xie et al., 2021). The presentation of information presented in digital technology is limited to two dimensions and can be presented in a three-dimensional environment (Cappannari & Vitillo, 2022; Mahendru et al., 2024). Moreover, advances in digital technology allow users to have real intelligence with these virtual objects in the presence of virtual reality (VR) technology (Al-Khassawneh, 2023; Mourtzis et al., 2022).

VR is a technology that presents a simulation of a phenomenon in a virtual environment close to its original conditions. With VR, users feel like they are in another world because users are transported into a virtual environment and can interact with virtual objects. This technology supports a more realistic and simple presentation of information, especially for complex phenomena (Di Natale et al., 2020; Mufit et al., 2024). The incorporation of interactivity within the context of VR has been demonstrated to foster user engagement and motivation in the learning process (AbdelAziz et al., 2020; Arayaphan et al., 2022).

The acquisition of programming algorithms necessitates a certain level of motivation and engagement on the part of the learner. This is important because algorithmic learning requires a deep understanding of concepts and the ability to think logically and analytically (Cardoso et al., 2021). Students will have difficulty understanding the complex steps in compiling and implementing algorithms without active involvement. This learning process is theoretical and practical (Cardoso et al., 2021). Students need to practice drafting code and solving problems directly by directly implementing algorithms. Implementing media, teaching methods, and techniques that encourage active participation and provide interactive learning experiences is required to motivate students and facilitate optimal learning outcomes.
In learning Programming Algorithms, there are several problems that have an impact on low student learning outcomes. Learning on programming algorithm materials so far tends to focus on textual, which results in low student motivation in learning. This has a negative impact on student learning outcomes. The media used is generally only in the form of written textbooks, so student involvement in the learning process is also limited. The issue requires a solution in the form of instructional media tailored to the characteristics of programming algorithm materials and capable of supporting student learning outcomes.

The low learning outcomes of students and the limitations of learning media create gaps in the programming algorithm course. Therefore, this situation provides an opportunity to develop innovations that can enhance student engagement. Research shows that the application of videos, images, and flipped classrooms can help improve learning outcomes (Durak, 2020; Martínez-Carrascal et al., 2020). However, this method has limitations in supporting the visualization and delivery of material interactively, especially for students with diverse learning styles (Duan et al., 2020; Hasan et al., 2020; Samala et al., 2024a; Sobral, 2021). The use of media visualization in the form of videos and images has certain limitations in terms of its capacity to effectively convey the phenomenon of the problem being solved (Dewi et al., 2024; Mufit et al., 2022). The availability of 3D media provides support for presenting more complete information than 2D in supporting the visualization of material explanations (Mufit et al., 2024). Therefore, learning media that is more interactive and in accordance with the characteristics of programming algorithm materials is needed to increase student involvement in improving student learning outcomes (Horvat et al., 2022).

One form of innovative and interactive media that can be developed to support students' limitations in the form of 3D displays can utilize VR technology. VR allows the presentation of information and simulations in three dimensions and engages the user directly, as if in real conditions. VR technology provides support to students to apply various learning styles, such as visuals through 3D displays, kinesthetics through gesture interaction with 3D objects in the virtual environment, and audio through voice command interaction (Budi et al., 2023; Duklim & Hasan, 2024; Fortuna et al., 2023; Prahani et al., 2022). So, innovations to support student involvement in learning to improve learning outcomes can be applied by utilizing VR technology. The objective of this study is to ascertain the impact of the utilization of VR technology in comparison to traditional learning methodologies on the attainment of student learning outcomes in the context of programming algorithmic materials. The research question was as follows:

1. What were the results of improving student traditional learning in programming algorithm material?
2. What were the results of improving student learning of VR in programming algorithm material?
3. What was the effect of using VR compared to traditional learning in improving learning outcomes in programming algorithm materials?

2. Literature Review

2.1. Virtual Reality (VR)

VR was a technology that brought users into a digital environment, replacing the real world with virtual simulations. This technology allowed various real-world activities to be realized through virtual simulations (Chamorro-Atalaya et al., 2023; Mufit et al., 2023). VR involved sensory interactivity close to reality, such as a visual view of a virtual environment and movements like walking and interacting with virtual objects (Marougkas et al., 2024). The effects developed by the developers provided a sensation that was getting closer to the real world (George-Williams et al., 2020).

VR technology has become a trend and gained popularity in the last decade due to its advantages. It was applied in several sectors, such as education, gaming, and entertainment (Ansari et al., 2022; Barteit et al., 2021; Mäkinen et al., 2022; Marougkas et al., 2023; Samala et al., 2023b). VR offered good efficiency in presenting information that was close to the original. Complex phenomena in real environments could be simulated with VR technology. The observation presentation was delivered in a 360° display (Georgieva et al., 2021). VR devices were needed to interact with virtual objects to present realistic learning with VR. This technology was usually presented as VR glasses and joysticks that controlled the user's movements (LaValle, 2023; Raja & Priya, 2021). Users could also use body movements directly without a joystick, providing a closer interaction to reality for those familiar with the device.

VR experienced development in the education sector. In medicine, VR was used to simulate surgery preparation for students. In engineering, VR supports the preparation of real learning, such as the practice of machines, electrical circuits, nuclear systems, and computer systems (Mufit et al., 2024; Šiđanin et al., 2020; Xie et al., 2021). With VR, students can better understand before practising it in a real environment, reducing the likelihood of errors and associated costs. In engineering and informatics learning, VR enables simpler information. Through VR, informatics engineering learning offerings such as programming algorithms can be presented interactively through user interaction with virtual objects. This condition encourages students' interest and motivation in learning the material.

2.2. Programming Algorithm Courses

Informatics Engineering is a field of science that studies the application of information technology and computers for various purposes. Some common topics studied in Informatics Engineering included programming, information systems, databases, and computer networks. One of the basic materials that often experienced obstacles for Informatics Engineering students was programming algorithms. This material was related to the logic and formulation of problem phenomena in the real world that were solved as programming code (Aldobekhi & Abahussain, 2024). Programming learning in the past often focused on writing code without any interactivity that showed the results of the code. This condition decreased students' motivation and interest in learning, which, in turn, impacted their learning outcomes (Duklim & Hasan, 2024; Pazilah et al., 2024).

Therefore, in learning Informatics Engineering, direct practice is very necessary. By doing so, students can better understand how their code works and interacts with the real world, increasing motivation and achieving better learning outcomes. (Benbya et al., 2020). Digital technology is present through interactive programming algorithm materials (Adi et al., 2024). Interactive simulations are a valuable pedagogical tool that facilitates students' comprehension of the subject matter (Said et al., 2024; Zinovieva et al., 2021). The presence of simulations helps explain complex concepts more simply (Wong et al., 2020).

In the previous lessons, simulations were often presented as two-dimensional information, which had limitations regarding observation space and interactivity. This caused the information conveyed to be not completely intact. VR encouraged interactivity in engineering delivery (Soliman et al., 2021; Wannapiroon et al., 2021). Simulation in three dimensions was crucial in supporting informatics engineering learning. With three-dimensional simulation technology, students could learn by approaching more realistic phenomena (Dewi & Asnur, 2023; Di Lanzo et al., 2020). Systematic programming algorithm development with the presentation of interactivity in teaching encouraged the ability of students to solve programming codes (Malik et al., 2022). This technology allowed the presentation of information closer to reality before students practised it directly.

VR is a very relevant technology supporting the presentation of informatics engineering phenomena and experiments in a virtual environment. With VR, phenomena and experiments can be presented in a context close to the real world(Kugurakova et al., 2021). It is, therefore important to investigate the influence of VR in learning informatics techniques for programming algorithm materials to gain a deeper understanding of its impact.

3. Methodology

The methodology adopted in this study is quasi-experimental. This method involves control and experimental classes in the observation process and compares the results. Each group is assessed using a different learning method. The results of learning before and after as a data source in this study. The design of the study is presented in Figure 1.

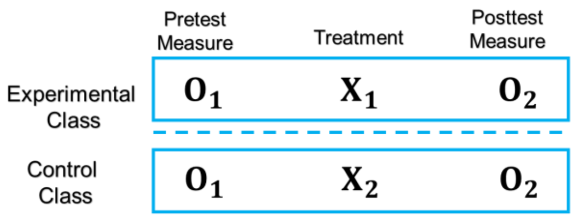

Figure 1. Quasi-Experiment design

Figure 1 shows a quasi-experimental design involving two classes. The population in this study consists of six classes. Sample selection was done through random sampling techniques from the six classes, and class A and B were selected as research samples. Class A was chosen as the control class with 19 students, while Class B was chosen as an experimental class with 16 students. This selection aims to ensure a fair comparison between the two classes in the study. Students who participated in this study were enrolled in the programming algorithm course at Universitas Negeri Padang. Of the participants, 22 were female, and 13 were male, aged 19 to 20. Before learning, both classes are pretested to measure initial ability. The initial data was used as a comparison after learning with different treatments. Posttest to measure students' final abilities after learning.

3.1. Research Implementation

This study applies a quasi-experimental method by dividing students into control and experimental classes. The control class underwent traditional learning, using printed books and whiteboards to explain the material, while the experimental class received a learning treatment using VR technology. The VR technology applied includes material on programming algorithms in a VR environment. The learning products applied in the experimental classroom with VR technology are presented, as seen in Figure 2.

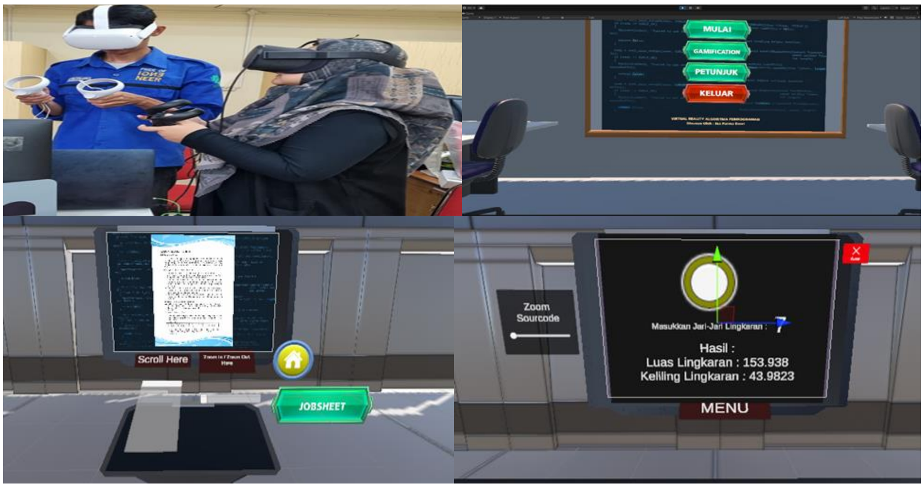

Figure 2. VR technology

Figure 2 presents the interface design and navigation in the VR technology used in this study. Every student uses a VR device consisting of VR glasses and two joysticks to control movement. The design display includes a description of the material on programming algorithms, allowing students to interact with virtual objects. Learning in a VR environment consists of several rooms connected by menus to access and unlock these rooms. Students can identify problem phenomena that must be solved systematically, such as designing a network system and decoding algorithms to calculate the area and circumference of a circle. Information is presented systematically and sequentially, with the outgoing form of a circle designed based on code in a virtual environment. This encourages interactive learning that displays images and creates virtual objects. In addition, the VR environment also presents a quiz room to measure understanding of the completed case studies.

3.2 . Data Collections and Data Analysis Technique

The data has been collected using test instruments to measure students' initial and final abilities through pretests and posttests. Statistical tests processed the data, including normality, homogeneity, Wilcoxon, and Mann-Whitney tests. The normality and homogeneity tests were carried out as a preliminary test to determine the suitability of statistical tests. If the significance value sig < 0.05, the data is considered undistributed normally and not homogeneous. The Wilcoxon test was used to measure the improvement of learning outcomes in each group, while the Mann-Whitney test was used to compare the learning effects between the control class and the experimental class to determine which method was more effective. The hypothesis of this study is tested based on the Z-value of the table and the significance value sig (2tailed), with the null hypothesis stating that VR learning is more effective than traditional learning, accepted if the calculated Z-value is less than -1.96 or the value sig (2tailed) < 0.05.

4. Results

The research data consists of pretest and posttest results. The data is statistically tested to observe the impact of learning. In the initial stage, the data is tested for normality and homogeneity to determine the data distribution. The preliminary test results are displayed in Table 1.

Table 1: Normality Test and Homogeneity Test

Test	Class	Normality Test Kolmogorov-Smirnova			Homogeneity Test Levene Statistic		
		Statistic	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Pretest	Control	0.171	19	0.004	4.675	33	0.038
	Experimental	0.234	16	0.009			
Posttest	Control	0.216	19	0.002	51.782	33	0.000
	Experimental	0.380	16	0.000			

Table 1 informs the homogeneity and normality test. The normality test was carried out with Kolmogorov-Smirnov, and the homogeneity test with Levene's statistic. The interpretation of the normality and homogeneity test results is based on the significance value (sig); If the sig value obtained < 0.05, then the data is considered abnormal and not homogeneous. Based on the data obtained, the sig value < 0.05 indicates that the data is not normally distributed or homogeneous. Therefore, further testing was carried out using nonparametric statistical tests, namely the Wilcoxon test to measure the improvement of learning outcomes in each class and the Mann-Whitney test to compare the learning effect between the control and experimental classes.

4.1 Student Learning Outcomes with Traditional Learning

The test data results in the control class were tested statistically. The statistical test carried out was the Wilcoxon test. This test is to see the effect of teaching by applying traditional teaching. The test results in the control class through the Wilcoxon test are presented in Table 2.

Table 2: Control Class Wilcoxon Results

Information	Pretest-Postest
Negative Rank	1
Positif Rank	16
Ties	2
Total	19
Z-value	-3.481
Sig (2tailed)	0.001

Note: Z_{table} -1.96

Table 2 informs the Wilcoxon test results from the control class's test data. There was a decrease in 1 score from students, 2 scores were at the same score, and 16 students obtained an increase in learning outcomes. The Z-value obtained was -3.481 with an sig (2tailed) value of 0.001. The Z-value obtained is compared to the critical Z_{table} of -1.96 at a significance level of 0.05, indicating that the Z-value is much lower than the Z_{table}. This indicates that there is a statistically significant difference between the pretest and posttest in the control class. The very small sig (2tailed) of 0.001 further strengthens the evidence that there is a significant improvement in learning outcomes in the control class.

4.2. Student Learning Outcomes with VR Learning

The test data results in the experimental class were tested statistically. The statistical test carried out was the Wilcoxon test. This test is to see the effect of teaching by applying VR teaching. The test results in the experimental class through the Wilcoxon test are presented in Table 3.

Table 3: Experimental Class Wilcoxon Results

Information	Pretest-Postest
Negative Rank	0
Positive Rank	16
Ties	0
Total	16
Z-value	-3.542
Sig (2tailed)	0.000

Note: Z_{table} -1.96

Table 3 informs the Wilcoxon test results from the experimental class's test data. The Wilcoxon test showed that positive ratings indicated improved learning outcomes across students in the experimental class. The Z-value obtained was -3.542 with an sig (2tailed) value of 0.000. The Z-value obtained is compared to the Z_{table} of -1.96 at a significance level of 0.05, indicating that the Z-value is much lower than the Z_{table}. This indicates that there is a statistically significant difference between the pretest and posttest in the experimental group. The very small sig (2tailed) of 0.000 further strengthens the evidence that there is a significant improvement in learning outcomes in the experimental class. Therefore, it can be concluded that VR learning interventions or treatments significantly improve learning outcomes.

4.3. The effect of learning with VR compared to traditional learning on learning outcomes

Comparative testing was conducted to investigate the best learning method. Learning outcomes in both classes varied. Data was obtained from test results through pretests and posttests. Changes in learning outcomes in both classes have been presented, as shown in Figure 3.

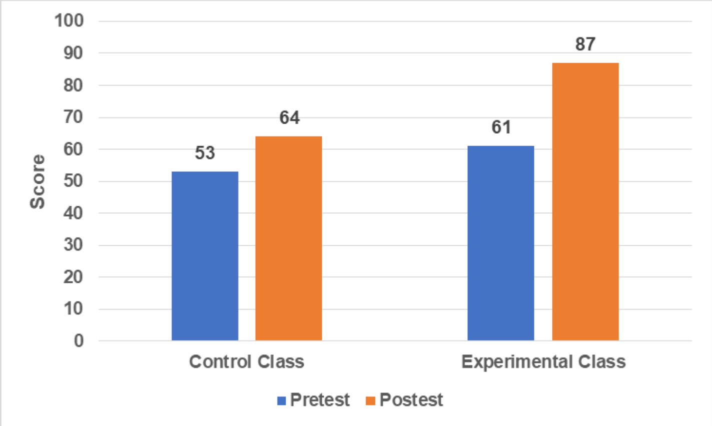

Figure 3. Pretest and Posttest Score Results

Figure 3 shows a graph of the score results of both classes. In traditional learning, student scores increased from 53 to 64, while in VR learning, student scores increased from 61 to 87. Both classes got an improvement in posttest results. Learning with VR shows a greater increase. To test the best effect between two classes, the Mann-Whitney test is conducted. This test provides information about significant differences between the classes. The Mann-Whitney test data, presented in Table 4, helps identify which treatment is more effective in improving learning outcomes.

Table 4: Mann-Whitney Test Results

Information	Results
Mann-Whitney U	165.00
Z-value	-4.579
Sig (2tailed)	0.000

Note: Z_{table} -1.96

Table 4 provides the results of the Mann-Whitney test for both classes. In the comparative analysis between the experimental and control classes, a U value of 165.00 with a Z-value of -4,579 and Sig (2tailed) of 0.000 were obtained. Based on a significant Z-value that far exceeded the threshold of -1.96 at a significance level of 0.05, it can be concluded that there was a significant difference in learning outcomes between the two groups. A sig (2tailed) value of less than 0.05 reinforces that learning using VR technology has a better influence than traditional learning. Thus, the use of VR has proven to be effective in improving learning outcomes on programming algorithm materials.

5. Discussion

Traditional learning has a limited impact on improving learning outcomes. For example, student learning outcomes increased from 53 to 67 before and after learning. This suggests that traditional learning does not significantly support improved learning outcomes (Brown et al., 2020). Previous research also revealed that traditional learning is limited in conveying information, resulting in relatively low student learning outcomes. These limitations include the high cost of repetitive practices compared to the use of digital media.

Learning has traditionally been assessed well in small groups but has a larger number of weaknesses with one supervisor (Wang et al., 2021). In these conditions, technology is needed to support student involvement equally. The research demonstrates the utilisation of various tools and techniques to facilitate the learning process, one of which is the incorporation of virtual technology. (Kanika et al., 2020; Marta et al., 2024)). The choice of techniques in learning has an influence on learning outcomes (Garcia, 2021).

Learning with VR shows that the achievement of learning outcomes increased from 61 to 87 using VR. This shows that VR has a significant impact on improving learning outcomes. Previous research also supports these findings, suggesting that VR allows for iterative learning at a more cost-efficient rate (Price & Price-Mohr, 2019; Soliman et al., 2021). Digital technology in VR also provides information in three dimensions, providing a wider scope of information delivery (Dos Anjos et al., 2021; W. Huang & Roscoe, 2021). Interactive learning in programming algorithms in the form of games encourages students' interest in learning them (Khamis et al., 2024; Zhan et al., 2022).

VR gives students the freedom to support realistic experimental activities in learning (Mufit et al., 2024). The use of VR in algorithms and programming provides a positive experience for students and teachers in the learning process (Carter & Egliston, 2023). However, VR has challenges in the potential risk of data loss if not properly set up (Carter & Egliston, 2023). The use of virtual environments provides a new interactive experience for users in data processing (Paiva et al., 2022). The implementation of technological devices used in programming education significantly influences students' computational abilities (Kirçali & Özdener, 2023). Research reveals that learning design by utilizing VR can support student motivation to learn and is better than conventional learning (Kao & Ruan, 2022). The presence of VR opens up opportunities to reform the training process in a virtual environment before entering the actual instructive environment (Tan et al., 2022)

The comparison between learning outcomes with traditional media and VR shows significant differences. Learning with VR is considered more effective than traditional learning. The capacity of VR to facilitate repetitive interaction with virtual objects enables users to identify solutions to problems, which has limited tools and scope and cannot be done with traditional learning (Oje et al., 2023; Soliman et al., 2021). Data collection in experimental activities in a virtual environment allows students to make decisions with the help of virtual simulations (Araiza-Alba et al., 2021). The presentation of information in VR encourages students' interest in reading (Damopolii et al., 2022; Piriyasurawong, 2020).

The combination of learning and play in understanding programming material increases students' motivation to learn (Figueiredo & García-Peñalvo, 2020). VR is designed in the form of a combination of play and learning, with interaction through virtual objects to solve a case study of a problem. The positive effects produced by VR in learning open up greater potential for the implementation of the technology in programming learning (Pirker et al., 2020; Agbo et al., 2021). VR provides better support in encouraging student engagement in the learning process (Zahabi & Abdul Razak, 2020).

The findings of this study contribute to the completion of the report on the impact of VR on the learning of programming algorithms. Learning with VR contributes to presenting various forms of learning styles so as to support student involvement in learning compared to the application of traditional learning (Lin et al., 2022). VR, as a 3D visualization technology, has a strong relationship with supporting students' learning styles that are dominated by visuals. In addition, controllers in VR allow movements that tend to match the students' kinesthetic learning styles (C. L. Huang et al., 2020). The interactivity presented by VR provides advantages over traditional learning in supporting student involvement in learning. VR learning offers better interactivity and can increase student engagement in a virtual environment (Al Amri et al., 2020). VR is effectively used in learning in higher education to improve the mastery of concepts (Pande et al., 2021; Tarng et al., 2022). VR supports the development of techniques to improve learning outcomes (Halabi, 2020). In contemporary learning, VR supports good achievement in learning programming algorithms compared to traditional methods. Consequently, the utilisation of VR has been demonstrated to be an efficacious methodology for the implementation of algorithmic instructional materials, thus enhancing student learning outcomes.

6. Limitations

The research focuses on reporting the results of comparing the impact of learning implementation with VR and traditional learning. There are limitations in the implementation of research, especially in the data collection process. The data collected was limited to learning outcomes before and after learning, with a relatively small sample size. This condition is based on the assumption that the ideal conditions for learning in a classroom are applicable to a class of a given number of students. Further investigation for other researchers could investigate its impact on larger sample numbers. In addition, further research could investigate the relationship between VR's impact on health, time of use, and other 21st-century skills. Furthermore, VR can be developed to a greater degree of immersion, such as in the form of mixed reality, spatial computing, and extended reality, to increase the reality of the displayed objects to become more real.

7. Conclusion

The results of the statistical tests indicate that the traditional learning approach to the subject of programming algorithms has resulted in enhanced student learning outcomes. The majority of students exhibited positive growth, although a subset demonstrated no change or a decline in their results. The traditional method was found to significantly enhance student learning outcomes between pretest and posttest scores, thereby demonstrating its effectiveness in improving student understanding. In contrast, the use of VR demonstrated even more pronounced improvements in learning outcomes compared to the traditional learning approach. All students in the VR class demonstrated positive growth. These findings suggest that the utilisation of VR in an educational context can have a more pronounced effect on student learning outcomes, thereby underscoring the efficacy of this approach in facilitating comprehension of programming algorithmic material. While traditional methods can enhance students' basic knowledge and analytical skills, they often face challenges in understanding abstract concepts, particularly for those who are visual or kinesthetic learners. The utilization of VR facilitates the presentation of more realistic programming simulations, thereby assisting students in comprehending algorithms with greater clarity and enhancing their engagement. When compared, VR-based learning has been demonstrated to be more effective than traditional methods. Comparative analysis indicates that students who learn using VR experience more favourable learning outcomes. This suggests that the VR method has a greater advantage in improving student learning outcomes in programming algorithm material compared to traditional teaching methods.

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