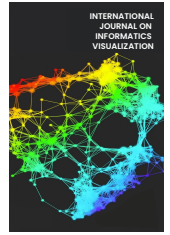




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Virtual Reality in Algorithm Programming Course: Practicality and Implications for College Students

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Abstract—Virtual Reality (VR) is one of the revolutionary technologies in education that can simulate learning interactively and realistically. The reliability of VR supports various variations in learning, including learning programming algorithms. This research aims to design and develop VR in learning programming algorithms. The ADDIE model is applied in this study to develop products through the stages of analysis, design, development, implementation, and evaluation. The analysis of learning problems shows the unavailability of interactive learning media that can support various learning styles of students in programming algorithm materials. Therefore, this VR learning design integrates various elements of students' learning styles, including visual, audiovisual, kinesthetic, and reading. The product developed is in the form of a VR application that presents learning by having a variety of learning styles. Audiovisual displays are presented in a VR environment, while kinesthetic interactions are obtained through user movements, and material information and readings are presented in a VR environment. The data collected included the results of a practicality and effectiveness test involving sixty-six students. The results of the practicality test show that this VR product is practical to use based on the indicators of convenience, attractiveness, efficiency, and benefits. Meanwhile, the effectiveness test shows that this VR product can improve learning outcomes better than traditional learning methods. Overall, the VR products developed have proven to be practical and effective in learning programming algorithms. The presence of VR, which presents a variety of realistic displays in a virtual environment, opens opportunities for further research related to distance learning through VR technology as well as an analysis of the impact of VR on health.

Keywords— Algorithm programming; learning outcomes; programming; virtual reality.

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I. INTRODUCTION

The development of digital technology has affected the education sector, where the use of digital technology in the teaching and learning process is becoming increasingly common. Education currently focuses on innovation and optimal use of technology, the internet, and information, which is marked by the transition from the 4.0 revolution era to the 5.0 society era [1]. These changes are expected to support interaction between students and teachers in adapting to the use of new technology in learning [2], [3], [4].

Educators have started using technology extensively because it improves learning outcomes. Education in Indonesia, which previously focused on developing logical thinking, is now shifting to developing creative, analytical,

and innovative thinking. All of this must be responded to by improving the quality of learning and curriculum in colleges and schools, considering the need for every graduate to not only be proficient in their field, but also have critical thinking skills and soft skills to face the challenges of the digital era [5], [6]. Digital technology presents various forms of creative media to support training and learning [5].

In the last decade, VR technology has become a trend and popular because of its advantages. VR is a learning technology that can potentially support engaging learning [7]. VR has been widely used in various fields of education. VR is a learning technology that can potentially support interactive learning [7]. VR technology has been applied in various fields, such as education, gaming, and entertainment [8], [9]. In medicine, VR is used to simulate surgical preparation for students. In engineering, VR supports the

preparation of real learning, such as the practice of machines, electrical circuits, nuclear, and computer systems [10], [11], [12]. With VR, students can better understand before applying it in a real-world environment, reducing potential errors and associated costs [13].

VR offers good efficiency in presenting information that is close to the original. Complex phenomena in the real environment can be simulated with VR technology, with the observation display presented in a three-hundred-sixty-degree view [14], [15]. VR technology allows users to enter a digital environment, replacing the real world with virtual simulations. This technology allows various real-world activities to be realized through virtual simulations [20]. VR offers sensory interactivity that is close to reality, such as the visual display of virtual environments and movement, such as walking and interacting with virtual objects [16], [17]. The effects developed by the developers create a sensation that is getting closer to the real world [18]. VR provides various forms of interactivity in learning, creating a more engaging and profound learning experience. This interactive technology simplifies explanations of complex concepts in a more straightforward manner [19], [20].

The interactivity of technology in technical education is crucial to support student engagement and understanding, especially in the field of informatics engineering. One of the challenges frequently faced by Informatics Engineering students is comprehending programming algorithms. This material discusses logic and how to solve real-world problems through programming code [21], [22]. Traditional teaching methods, which often rely on lectures and two-dimensional simulations, have limitations in providing a deep learning experience [23], [24]. The implementation of technology in previous learning primarily utilized e-books and flipbooks, which presented videos and images with limited information in the form of instructional sentences and pictures without providing interactive simulations [25], [26], [27]. This is unable to meet the needs of students who have various learning styles in solving problems. As a result, students' learning outcomes in programming algorithm material tend to be low.

Technological characteristics that support a variety of students' learning styles are indispensable to overcome academic gaps. Differences in students' learning styles can have a negative impact on learning outcomes, creating gaps in academic achievement. By using appropriate media, such as

virtual reality (VR) technology, learning can be adapted to students' diverse learning styles in an interactive form. Therefore, it is important to use supportive technology in an approach that is in accordance with the characteristics of students' learning styles in order to improve learning outcomes effectively.

The design of technology in the form of VR is one of the new innovations needed to meet the various learning styles of students and support improved learning outcomes. Because VR introduces higher interactivity in delivering materials [28], [29]. 3D simulation becomes crucial in Computer Science learning, allowing students to study in a more realistic and close-to-real-life manner.

The various advantages presented by VR provide new innovations in learning to overcome various problems in the learning process. The limitations of traditional media in supporting interactive, communicative, independent, and realistic learning in learning programming algorithms open up opportunities for the development of learning support media. The presence of VR as an innovative technology offering various latest features is an alternative solution for media development. The development of VR in learning informatics engineering to support practical and effective learning is an innovation in learning programming algorithms. Thus, this study aims to answer the following research questions:

- How has the VR learning design been developed for programming algorithm material?
- How does VR support practical learning in programming algorithm material?
- How effective is VR in supporting the learning of programming algorithm materials?

II. MATERIALS AND METHOD

A. Research Methodology

This research is included in the design and development category, which uses the stages of the ADDIE development model. The ADDIE model consists of five stages: analysis, design, development, implementation, and evaluation. Each stage in the ADDIE model plays a key role in identifying the problem and finding the right solution to the problem. The stages in the VR product development process are presented in Fig 1.

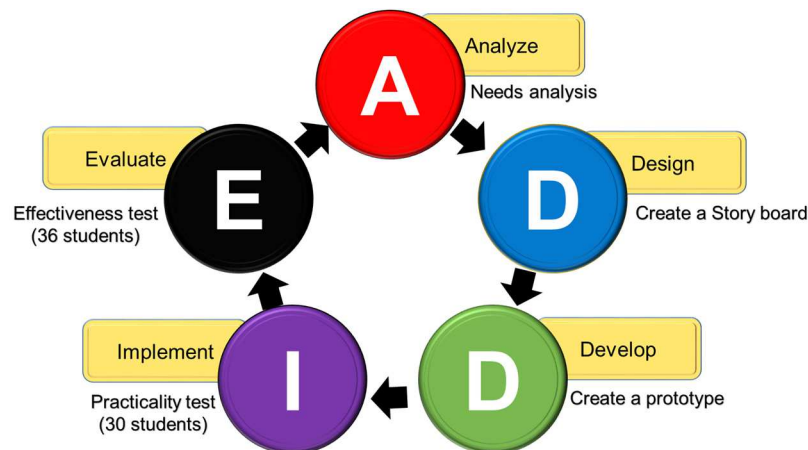


Fig. 1 ADDIE development model stage

Fig. 1 shows a view of the ADDIE development model. The first stage in the development process is carried out through analysis. The analysis aims to find problems in learning. At this analysis stage, interviews and surveys are conducted to obtain information about learning problems in programming algorithms. The results of the analysis revealed that there were problems in learning, especially related to the availability of media and material explanations. Based on the results of this analysis, a design stage is carried out to describe the solutions needed to overcome the problem. This design stage is presented in the form of a flowchart that serves as a frame of reference at the development stage. In the development stage, the product is developed based on the design framework by integrating all the information collected into a digital learning medium. The products produced at this stage of development are prototypes of VR that are made. The next stage is the implementation of the prototype in learning, with students as the audience or users of the VR product. This implementation stage is known as the practicality test, which aims to measure the product's feasibility in learning. If the product proves to be practical, then the product can proceed to the evaluation stage. In the evaluation stage, the product that has been developed is used in learning to assess its effectiveness in improving learning outcomes. At this stage, research is carried out with the design of control and experimental classes. The research design at this implementation stage aims to compare the best and most effective learning methods to be applied in improving learning outcomes.

B. Data Collections and Participants

The data in this study were obtained from the practicality and effectiveness test results in teaching using practicality and effectiveness instruments. This research utilizes VR, with the results of the practicality test obtained from 30 students as target VR users. Meanwhile, the effectiveness test involved 35 students who were divided into a control class and an experimental class.

C. Data Analysis Technique

Data from the practicality test were processed using a percentage technique. The formulation of the results of the practicality test is processed using the equation presented in Equation 1.

$$V = \frac{(\text{Score From Expert} - \text{The Lower Score})}{(\text{Number of Category} (\text{Number of Expert} - 1))} \quad (1)$$

Equation 1 shows the formula used to process the practical results. The practical results are obtained from comparing the scores given by students to the maximum score. The standard score range of the practicality test is used to interpret the results of the practicality test. If the practicality score (N) value is > 60 , then the product developed is considered practical. Effective data processing is carried out through several stages of statistical testing, by utilizing SPSS 26 software. The initial testing stage includes a normality test. If the test result data is abnormal, then an in-depth statistical analysis is carried out through the Wilcoxon and Mann-Whitney tests. The Wilcoxon test aims to see the effect of improving learning outcomes in each class. The null hypothesis in the Wilcoxon test is that there is no considerable influence between the implementation of learning with VR

and traditional learning in improving student learning outcomes. If the significant value (sig) < 0.05 , then the null hypothesis on the Wilcoxon test is rejected. The Mann-Whitney test was conducted to see the most effective effect in improving learning outcomes. The null hypothesis in the Mann-Whitney test is that learning with VR is no more effective than traditional learning in improving learning outcomes. The conclusion is drawn if the value of the sig < 0.05 or the z-table < -1.96 , then the null hypothesis is rejected.

III. RESULTS AND DISCUSSION

A. How has the augmented reality learning design been developed for programming algorithm material?

Analysis is the first stage in collecting data to find problems in learning. The analysis results were obtained from interviews and observations related to obstacles in learning programming algorithms. Based on the results of the interviews, several problems were found in learning, including the diversity of students' learning styles. Some students have kinesthetic, auditory, visual, and reading learning styles. This diversity is a challenge in presenting learning materials effectively. The observation results also inform that current learning utilizes limited media, such as whiteboards and books, as a source of material explanation. This condition has limitations and cannot support learning for students with diverse learning styles. Based on the information from the preliminary analysis, media that can support interactive, creative, and communicative learning is needed.

In producing learning media products, the problems faced are the main considerations in designing the materials and stages implemented with the chosen technology. Creating a flow chart is especially important to produce a systematic learning product. At this stage, the design of the learning flowchart needs to be developed to be implemented in a VR environment. VR products are designed based on flowcharts, as shown in Fig. 2.

Fig. 2 shows a flowchart in VR product development. This product was developed by paying attention to the characteristics of students' learning styles. The initial display of VR products started in the engineering faculty's lecture hall. The building presents several rooms designed based on the characteristics of students' learning styles. These rooms include visual, audiovisual, reading, and kinesthetic learning style rooms. Each room displays learning materials presented in a VR environment. In the final stage of learning, evaluations involving projects and tests are presented interactively in a VR environment.

Based on the learning design, the selection of topics in VR is the material of programming algorithms. In developing VR, the selection of development applications is needed to realize the design and produce the appropriate solution. In the development of the VR environment, 3D object construction is carried out through an object modeling application in the form of Blender. Three-dimensional objects are arranged and interacted with in Unity applications. All interactions between objects are arranged interactively to produce a VR environment. This product is designed with a VR application format that can be installed on VR devices such as Oculus.

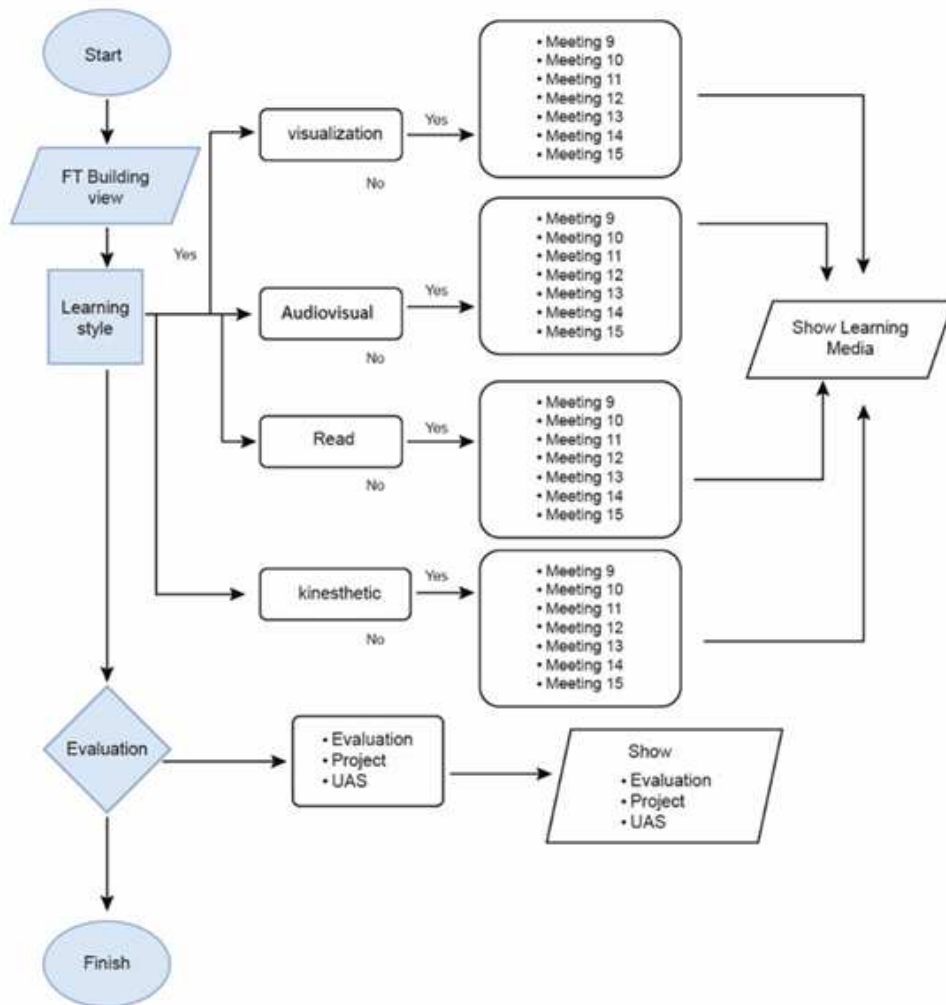


Fig. 2 Learning design flowchart in VR

VR products are designed based on solutions to overcome existing problems. VR is designed to support the presentation of students with different learning styles. This challenge is related to the presentation of diverse abilities. The

implementation of design-oriented product development is arranged in a flowchart to produce products that are in accordance with the learning targets. The form of the VR development results is presented as shown in Fig. 3.

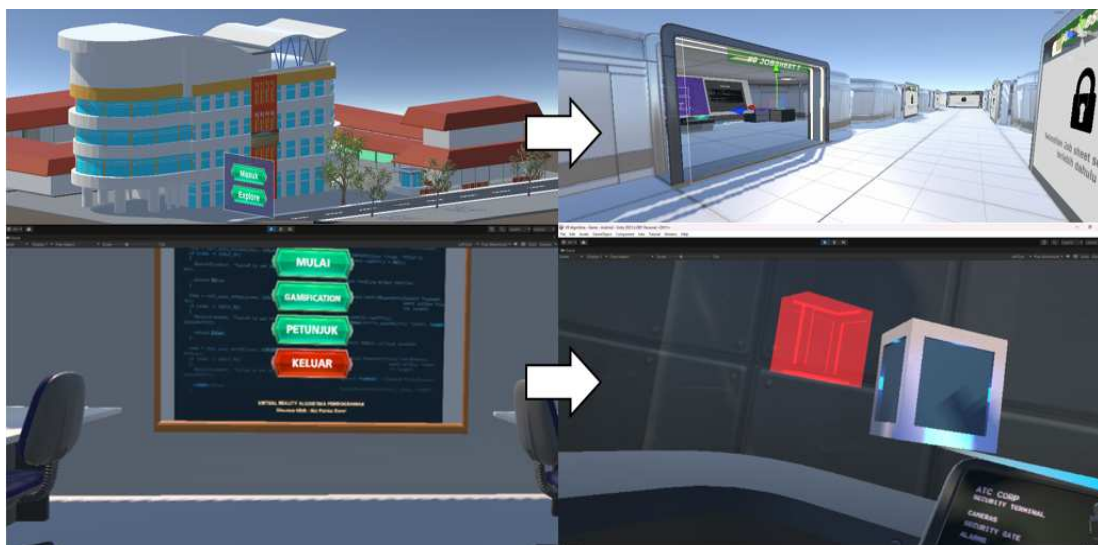
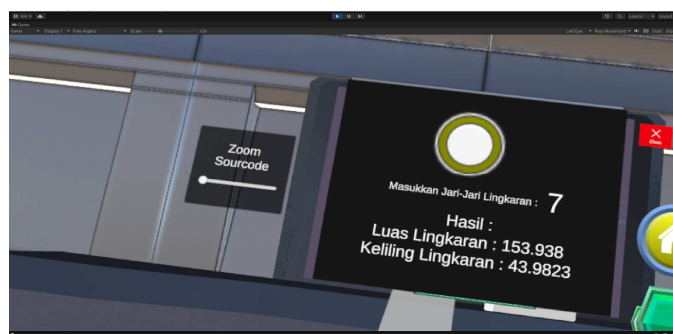


Fig. 3 Learning design flowchart in VR

Fig. 3 shows a visual display in a virtual environment. In this virtual environment, there are several menus available for access between rooms. The initial display page starts from the appearance of the lecture building as the initial access page to the virtual learning room. On the first page, there is a menu of instructions for using VR and learning guides in a VR environment. Instructions in VR provide information about



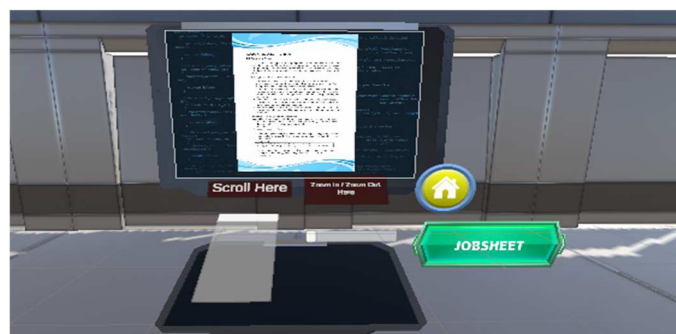
Audiovisual



Visualization



Kinestetik



Reading

Fig. 4 Presentation of learning in the form of visual, audiovisual and kinesthetic in the VR environment

Fig. 4 shows the shape of a virtual environment that supports learning with various student learning styles. In this environment, a computer screen display allows access to learning materials in the form of videos and job sheets. In other parts, there are several options for case study learning access, such as solving the problem of fruit array arrangement. Students interact directly with the object and are asked to arrange a sequence of fruits based on the given algorithm array data. In addition, in the reading section, students are presented with job sheets related to learning materials and information that supports knowledge about programming algorithms in a VR environment.

Four learning style options are available in the virtual environment: audiovisual, visual, reading, and kinesthetic. The navigation buttons on the learning style selection provide access to virtual spaces that match that learning style. For a visual learning style, students can explore the room and observe the information presented on each table in the form of a virtual exhibition. Meanwhile, the audiovisual learning style provides virtual videos, where students can select the video, they want to learn through the available menu. In kinesthetic learning, students face case studies and problem-solving exercises directly. They gain access to a wide range of information in the virtual environment by searching for supporting information through active exploration, which is then used to solve problems.

The VR environment is designed with virtual games to support interactive learning and engage all students' learning styles. The maze game tests students' visual, kinesthetic, and

learning methods in a VR environment. On the menu page, access to several rooms is provided to explore different types of media developed in a virtual environment. A variety of three-dimensional objects and interactions represent learning abilities with a variety of learning styles. The presentation of spatial forms that support learning in a variety of visual, audiovisual, and kinesthetic learning styles is shown in Fig. 4.

audiovisual skills. During the game, students must come out of the maze by opening each portal, answering questions, and providing information. The correct answer opens access to the next room, while the wrong answer requires students to search for an alternative answer and open an additional portal. This maze activity allows students to directly engage in virtual exploration, read questions, and analyze visual objects, so the gamification stage plays a role in activating all student learning styles and making learning more interesting.

VR products have been designed based on flowcharts to produce quality products. A flowchart in the digital product development process serves as a guide in design. A flowchart in the digital product development process serves as a guide in design. VR was developed following a flowchart to present a variety of activities in a virtual environment. The result of the VR product is presented as an application installed on Oculus devices, one of the best technologies for exploring virtual environments. VR devices allow for movement, navigation, and user interaction with virtual objects.

The developed VR allows for the interactivity of movement and interaction with virtual objects. VR products are designed with the characteristics of students' different learning styles in mind. The result of this design is an innovation in VR development that considers elements of student learning styles. This research reveals the importance of interactive media in supporting the diversity of students' learning styles in achieving the same learning goals [30], [31]. Visualization in VR has been presented, taking into account the audiovisual, kinesthetic, visual, and reading learning styles. Learning

interactions in VR have been presented, considering various learning styles.

B. How does VR support practical learning in programming algorithm material?

The VR products that have been developed are tested for practicality. This practicality test involves students as users. This testing stage involves 30 students to obtain information about the feasibility of the product when implemented in learning. The test result data was obtained from practical instruments filled in by students to assess VR. The results of the practicality test are presented as shown in Table I.

TABLE I
PRACTICALITY TEST RESULTS

Indicator	Score (%)
Ease of Use	98.0
Attractiveness	97.0
Efficiency	96.7
Benefits	98.7
Average	97.6

Table I displays the practicality of VR products divided into indicators of ease of use, attractiveness, efficiency, and benefits. The information on the ease-of-use indicator shows a score of 98, which indicates that this product is very practical. This score indicates that the display and navigation menus in the VR environment run smoothly. On the attractiveness indicator, a score of 98 was obtained with a very practical category. These results show that the display of rooms, menus, and virtual objects supports students' interest in learning and minimizes negative attraction for students. The efficiency indicator obtained a practicality score of 98 in the very practical category. This information reveals that VR products support practical and efficient learning in explaining material with various types of learning styles. In the benefit indicator, a score of 97.6 was obtained, which is in the very practical category. These results indicate that this product provides benefits for students with different learning styles and can be adjusted to students' learning desires. This usefulness supports practical learning in explaining the material concisely.

VR also presents learning games to support students' attraction and interest in learning. Games in learning encourage students' curiosity, interest, and interest in exploring events to solve problems [32], [33]. VR presents games in the form of problem-solving through case studies in the form of mazes, which supports strengthening students' problem-solving skills. Presentation of game development as an evolution in innovative and interactive learning [34]. The variations of interactivity presented in the VR environment provide support for improving the learning process based on the learning style of each individual, thus facilitating more optimal practical learning outcomes.

The appeal of digital projects in the form of VR must display uniqueness that encourages students' curiosity in learning [35]. VR brings virtual objects, virtual learning spaces, and games to realistic learning, encouraging students to explore further and acquire learning information [36]. In terms of efficiency and benefits, VR has proven to be effective in helping students understand the material. However, VR requires technical guidance before it can be used in learning.

VR technology, as the latest technology and still limited in daily use, requires directional guidance and guidance information to support efficiency in learning by utilizing VR [37].

C. How effective is VR in supporting the learning of programming algorithm materials?

Data on effectiveness results were obtained from the control class and the experimental class. Learning is carried out in two treatments: VR and traditional learning. Learning effectiveness data was analyzed using a normality test using the Kolmogorov-Smirnov test. The normality test results obtained a value of $p < 0.005$, indicating that the data in the control and experimental classes are not normally distributed. These results indicate the need to conduct further statistical tests to assess the effects of each learning method through the Wilcoxon test. The results of the Wilcoxon test are presented in Table II.

TABLE II
WILCOCON TEST ON CONTROL YAMS AND EXPERIMENTAL CLASSES

Information	Control Class	Experimental Class
Number of Students	19	16
Negative Rank	1	0
Positive Rank	16	16
Ties	2	0
Pretest	53	64
Posttest	61	87
Asymp. Sig (2tailed)	0.001	0.000

Table II displays the information on the Wilcoxon test result from the control class and the experimental class. The results of the Wilcoxon test showed that of the 19 students in the control class, there were one student who experienced a decrease in learning outcomes, two students with fixed grades, and 16 students who experienced an improvement. Meanwhile, in the experimental class, all 16 students experienced an increase without any decrease. The pretest result in the control class was 53, which increased to 64 in the posttest. In the experimental class, the pretest result was 61, which increased to 87 in the posttest. These results show that both classes have improved. Previous research also revealed that traditional learning has limitations in conveying information, so student learning outcomes are relatively low [38]. These limitations include the high cost of repetitive practices compared to the use of VR media [39].

The results of the Wilcoxon test showed an Asymp value. Sig (2tailed) < 0.05 indicates that the implementation of learning has a significant influence in supporting the improvement of learning outcomes. To determine the best influence in supporting learning, the data from both classes were further compared through the Mann-Whitney statistical test. The results of the Mann-Whitney test from both classes are presented in Table III.

TABLE III
MANN-WHITNEY TEST RESULTS

Information	Score (%)
Mann-Whitney U	165.00
Z Value	-4.579
Sig (2tailed)	0.000

Table III displays the results of the Mann-Whitney test from both classes' pretest and posttest data. The test results

showed a Mann-Whitney U score of 165.00, which affected learning. Based on the Z-value and p-value if the z-value is less than -1.96 and Asymp. Sig (2tailed) < 0.05, then the null hypothesis is rejected. The null hypothesis in this study states that learning with VR is not better than traditional learning. However, the results obtained show Z-value and Asymp values. Sig (2tailed) is smaller than the standard value of drawing conclusions, so the null hypothesis is rejected. This indicates that learning using VR is more effective compared to traditional learning. Thus, the use of VR in learning programming algorithms has proven to be more effective in improving learning outcomes. Previous research also supports these findings, which suggest that VR allows iterative learning at a more cost-efficient rate [28], [40]. Digital technology in VR also presents information in three dimensions, providing a wider scope of information delivery [41]. The use of VR in learning programming algorithms in the form of games encourages students' interest in learning it [42].

VR allows users to interact with virtual objects iteratively and find solutions to problems, something that traditional learning cannot do with limited tools and scope [39]. Data collection in experimental activities in a virtual environment gives students the ability to make more informed decisions when solving problems [43]. The presentation of information in VR encourages students' interest in reading to find solutions to problems [44], [45]. The VR innovation presented in this research complements the limitations of previous media in supporting material explanations. Previous learning utilized electronic books to support learning [46], [47].

Learning with VR offers better interactivity and can increase student engagement in virtual environments [48]. VR is effectively used in learning in higher education to improve mastery of concepts [49], [50]. VR supports the development of techniques to improve learning outcomes [51]. In contemporary learning, VR supports student creativity and provides better learning outcomes than traditional methods. Therefore, the use of VR in learning informatics engineering has proven to be practical and effective in supporting the improvement of student learning outcomes in programming algorithm materials.

IV. CONCLUSION

This study produces the development of a VR based learning application for programming algorithms and its implementation in higher education. The VR application is designed to accommodate various learning styles and simulate real-world programming environments using 3D simulations. The product is installed on Oculus devices, allowing students to interact with virtual objects and navigate the VR environment. The practicality of this application was tested, with students confirming its ease of use, attractiveness, efficiency, and benefits. In its implementation for learning, the VR application showed significant improvement in student learning outcomes, from pretest to posttest scores, compared to traditional teaching methods. Based on these findings, VR presents a viable alternative for instructional media in enhancing student engagement and learning outcomes in programming courses. However, this research has limitations in exploring the health impacts of VR usage on student acceptance, as well as the comparison between VR and Augmented Reality (AR). Further research is needed to

develop VR at a higher immersive level and integrate it with artificial intelligence (AI) to enhance learning effectiveness.

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