The Effectiveness of Virtual Reality in Mathematics for SPLDV Material

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A B S T R A K

Kurangnya media pembelajaran dan kreativitas guru dalam melaksanakan pembelajaran matematika mengakibatkan kurangnya pemahaman dan semangat siswa dalam pembelajaran matematika. Penelitian ini bertujuan untuk menganalisis desain, kelayakan, efektivitas dan respon guru dan siswa dalam melaksanakan pembelajaran virtual reality berbasis case based learning pada mata pelajaran matematika kelas VIII. Penelitian ini menggunakan model pengembangan Dick and Carey. Subyek penelitian terdiri dari dua orang ahli isi, satu orang ahli desain pembelajaran, satu orang ahli media pembelajaran, tiga orang siswa uji individual, sembilan orang siswa uji kelompok kecil, dan tiga puluh dua orang siswa uji lapangan. Metode pengumpulan data yang digunakan adalah wawancara, angket, tes dan dokumentasi. Teknik analisis data yang digunakan adalah analisis deskriptif kuantitatif, analisis statistik inferensial (uji t), dan uji N-Gain. Hasil uji ahli isi menunjukkan validitas sangat tinggi berdasarkan validitas Gregory. Uji ahli menemukan, persentase skor dinilai sangat baik. Berdasarkan perhitungan uji t diperoleh nilai signifikansi (Sig. 2-tailed) sebesar 0,000 lebih kecil dari 0,05 (p > 0,05), sehingga menolak hipotesis nol (H0) dan menerima hipotesis alternatif (Ha). Jadi, dapat disimpulkan terdapat perbedaan yang signifikan hasil belajar sebelum dan sesudah menggunakan virtual reality berbasis pembelajaran berbasis kasus. Perhitungan N-Gain menghasilkan skor sebesar 0,741 yang menunjukkan kategori tinggi sehingga dapat disimpulkan bahwa penggunaan pembelajaran virtual reality berbasis case based learning efektif meningkatkan hasil belajar siswa pada mata pelajaran matematika kelas VIII.

A B S T R A C T

The lack of learning media and teacher creativity in implementing mathematics learning results in a lack of students' understanding and enthusiasm in learning mathematics. This research aims to analyze the design, feasibility, effectiveness and response of teachers and students in implementing virtual reality learning based on case-based learning in class VIII mathematics subjects. The research uses the Dick and Carey development model. The research subjects consisted of two content experts, one instructional design expert, one learning media expert, three individual test students, nine small group test students, and thirty-two field test students. The data collection methods used were interviews, questionnaires, tests and documentation. The data analysis techniques used are quantitative descriptive analysis, inferential statistical analysis (t-test), and N-Gain test. The content expert test results showed very high validity based on Gregory's validity. The expert test found, the score percentage is considered very good. Based on the t-test calculation, the significance value (Sig. 2-tailed) of 0.000 is smaller than 0.05 (p > 0.05), rejecting the null hypothesis (H0) and accepting the alternative hypothesis (Ha). So, it can be concluded that there is a significant difference in learning outcomes before and after using virtual reality based on case-based learning. The N-Gain calculation produces a score of 0.741, which indicates a high category so it can be concluded that the use of virtual reality learning based on case-based learning is effective in improving student learning outcomes in class VIII mathematics subjects.

1. INTRODUCTION

Mathematics education at the junior high school level provides students with knowledge and helps shape their attitudes and mindset as they progress to higher education. Mathematics is a universal discipline that underlies the development of modern technology and plays a crucial role in various fields while contributing to human thinking (Cheng & Zhou, 2020; Liu et al., 2018). The benefits of studying mathematics encourage students to develop critical, logical, and systematic thinking skills that are highly useful in our daily lives (Sami Khan & Salman, 2020; Shadiq, 2014). Through observation and direct examples, it is hoped that students can grasp the understanding of a concept. The process of reasoning develops both inductive and deductive thinking patterns. Naturally, the illustrated flow must align with the students' abilities at the junior high school level to support the mathematics learning process in school (Pan et al., 2022; Tegeh & Dwipayana., 2019). The achievement of mathematics learning goals still encounters obstacles, one of which is that many students

perceive mathematics as a difficult subject, leading to a dislike for mathematics and even viewing it as something to be avoided (Damayanti & Wiarta, 2022; Skilling et al., 2021). Learning difficulties refer to a situation where students feel unable to learn properly, hindering the assimilation of the material. Based on observations during mathematics classes, the role of the teacher tends to be dominant and monotonous. The eighth-grade students at SMP Negeri 1 Negara appear passive, merely receiving what the teacher delivers. Reasons for students experiencing difficulties and passiveness in learning mathematics are related to mathematical concepts and calculations (Pambudi et al., 2020; Saputra & Semara, 2021). Interventions and extrapolations in the teaching and learning process will significantly determine the level of success that can be achieved. Another finding from interviews conducted with teachers is the limited use of instructional media, mainly relying on textbooks and supplementary books.

Specifically, in the topic of Systems of Linear Equations with Two Variables (SPLDV), which has a strong connection to everyday life, when teachers present complex cases in the form of realistic scenarios with real-world problems, students often feel confused when solving the problems. In SPLDV, students are taught the logic of mathematical thinking with contextual learning through cases that are often experienced in society. Ultimately, the teacher has to guide students in solving these case problems. The average student learning outcomes were around 60%, indicating that the achievement of learning outcomes has not reached its maximum potential. Given the situation on the ground, educators need the ability to develop appropriate methods, media, strategies, and instructional designs, taking advantage of current technological advancements. Furthermore, considering the characteristics of junior high school students who belong to Generation Z, as digital natives (Gentina, 2020; Prensky, 2001), they were born in a digital environment where their daily activities tend to involve the use of technological devices to seek information.

From these issues, a solution is needed by employing an appropriate teaching method and providing engaging instructional media. One effective instructional model that can help students solve SPLDV problems in the form of cases is the implementation of case-based learning methods. This method actively involves students in real-world problem situations that directly reflect their learning experiences (Syarafina et al., 2017; Wospakrik et al., 2020). To bring a learning experience to students, mathematics instruction needs to be enhanced by implementing technology. The use of technology in mathematics education helps students explore, discover, and understand concepts independently or with guidance (Jupri, 2018; Simamora et al., 2018). In the current digital era, educators need to innovate and design enjoyable learning experiences by integrating technology that combines content, pedagogy, and technology knowledge (TPACK) (Agustini et al., 2023; Nurhidayah & Suyanto, 2021). Virtual reality (VR) creates immersive simulations that allow users to engage in environments that closely resemble real-world objects and events, giving them a sense of presence in the virtual world. The use of virtual reality technology in the teaching and learning process is impressive and supports the presentation of materials in visual forms, capturing the high interest of users in virtual reality technology for education (Brůža et al., 2021; Fardani, 2020). Various studies have been carried out to implement virtual reality technology in learning, one of which is learning in the Indonesian Prehistory Course at the History Department of UNDIKSHA. The application of Gamification and virtual reality is very effective in increasing learning motivation and can involve students in the learning process related to historical places (Lampropoulos et al., 2022; Shi & Cristea, 2016). With VR, users feel more connected to content because they can personally interact with it and implement it. Currently the growth of smartphones and digital devices so many ideas have been created to keep up with the latest innovations. Unfortunately, there has not been much development of subject matter using VR in Indonesia. VR in Indonesia is still dominated by smartphone users with game applications (Sulistyowati & Rachman, 2017; Zhou et al., 2018; Zulherman et al., 2021). Therefore, the purpose of this study was to develop a case-based learning Virtual Reality (VR) product in mathematics in class VIII. The novelty in this research is that virtual reality roaming emphasizes solving problems in a given case. The cases presented are closely related to everyday life so it is hoped that through Virtual Reality (VR) students will be able to overcome problems related to SPLDV in everyday life.

2. METHOD

The type of research used by the researcher is a type of research and development known as Research and Development, utilizing the Dick and Carey Model. The Dick & Carey research and development model is one of the procedural models, suggesting the application of design principles tailored to sequential steps that need to be followed, so that all components work together to achieve and produce effective learning outcomes (Dick & Carey, 2019). Procedure refers to the sequential steps of research that must be followed one by one to complete a product. The following are the stages involved in developing case-based learning-based virtual reality. Preliminary Development Research or Introduction Research was conducted to comprehensively understand the profile of the 8th grade mathematics class through 7 open-ended questions in the form of a questionnaire distributed to 32 students of SMP Negeri 1 Negara and interviews with Mathematics teachers who

teach 8th grade regarding the mathematics learning process conducted so far. The analysis of needs to determine instructional goals was carried out through observations and interviews with teachers and students of 8th grade at SMP Negeri 1 Negara through questionnaires and interviews related to the use of instructional media during mathematics lessons, as well as analysis of needs for the content and curriculum of the 8th grade mathematics subject. This study including instructional analysis, analyzing student characteristics and learning contexts, formulating performance/specific objectives, developing assessment criteria, developing instructional strategies, selecting and developing instructional materials, designing and conducting formative evaluation. Three types of evaluations were carried out: a) expert evaluation, b) individual evaluation, group evaluation, and c) limited field trials, as well as pre-tests and post-tests based on the prepared questions. Revising instructional media, and conducting summative evaluation. The evaluation aimed to assess efficiency, effectiveness, and attractiveness of the overall design.

3. RESULT AND DISCUSSION

Result

Design and develop case-based learning-based virtual reality using the Dick and Carey development model. The selection of the Dick and Carey model is based on its orientation towards the development of learning products. The Dick and Carey model consists of 11 stages: (1) Needs analysis to determine objectives, (2) Identifying learning objectives, (3) Conducting instructional analysis, (4) Analyzing student characteristics and learning contexts, (5) Formulating performance/specific objectives, (6) Developing instructional strategies, (7) Developing assessment criteria references, (8) Selecting and developing instructional materials, (9) Designing and conducting formative evaluation, (10) Revising instructional media, and (11) Conducting summative evaluation. The content expert evaluation of the learning materials was conducted by Prof. Dr. Nyoman Parwati, M.Pd., a lecturer from the Master's Program in Educational Technology at Ganesha Education University, and Mr. Sendy Larinsa Clavinova, a mathematics teacher in Grade VIII at SMP Negeri 1 Negara. The content expert evaluation of the virtual reality learning was carried out with the aim of assessing the instructional content presented in this research product. The evaluation involved the use of a questionnaire or survey that had been previously developed. At the development stage, the first-time students will be given a class code to enter the virtual class. There will be several scenes, students will see the scene title. To study the material, students will select a scene title and be activated. Virtual reality products will invite students to take virtual trips according to the cases given. Students will follow the standpoint to explore as show in Figure 2.

Figure 1. Standpoint

In addition, to standpoints in VR roaming, students will be assisted by Pop Up info containing some information about the 3D objects displayed. Here is a Pop Up info image as show in Figure 2.

Figure 2. Pop Up Info

In VR roaming students will be given problems that are closely related to everyday life. Students will be stimulated to be able to find solutions to these problems. In the VR environment, students will also find several mathematical concepts that are used as answers to the problems. At the end of the exploration, students will be given a quiz that aims to find out students' understanding of the topics studied through VR media. The virtual reality product that has been developed and revised according to the assessment and feedback from experts is then subjected to individual user or student testing. The individual testing of the developed virtual reality media is conducted with three Grade VIII students from SMP Negeri 1 Negara. The subjects of the individual testing consist of students with high, medium, and low cognitive abilities. The results of individual trials are shown in Figure 3.
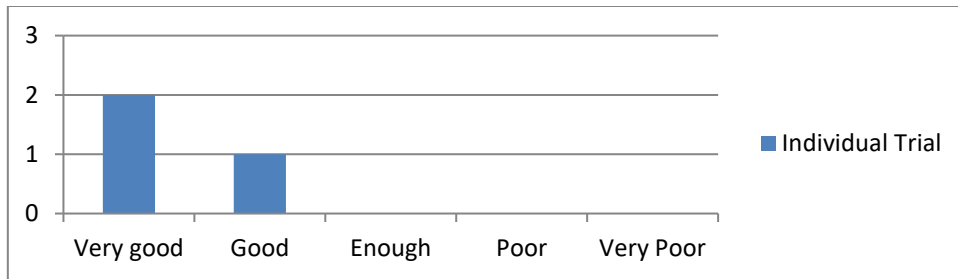

Figure 3. Graph of the Individual Test Results of Case-Based Learning-Based Virtual Reality

The subjects used in the small group trial consisted of 9 students divided into 3 groups, namely students with high, medium, and low cognitive abilities, with each group consisting of 3 individuals. The test small group is show in Figure 4.
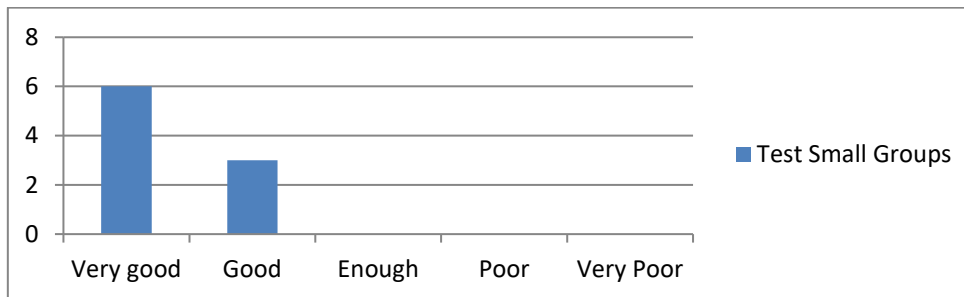

Figure 4. Graph of the Small Group Test Results of Case-Based Learning-Based Virtual Reality

The case-based learning-based virtual reality product, which has been validated by subjects in a small group trial, will undergo a field trial as the final stage of formative evaluation. The objective of the field trial is to identify how virtual reality performs in real-life conditions. Before being tested on students, the case-based learning-based virtual reality product is tested by a Mathematics teacher who teaches the 8th grade. The Mathematics teacher will fill out the provided instruments and provide feedback and suggestions on the virtual reality product. The field trial subjects consist of 32 9th-grade students from SMP Negeri 1 Negara with varying cognitive levels. The result is show in Figure 5.
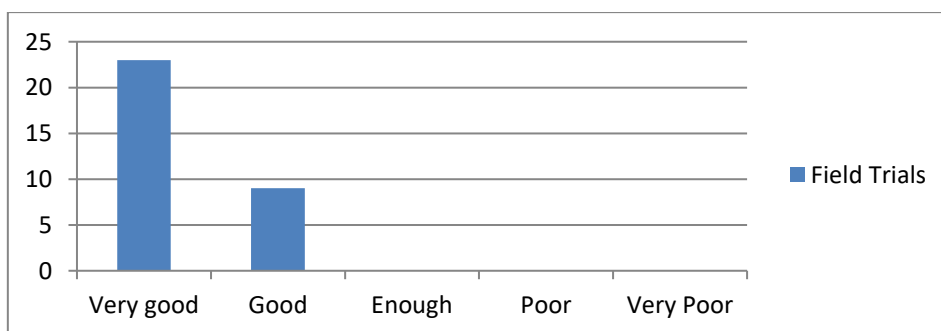

Figure 5. Graph of the Field Test Results of Case-Based Learning-Based Virtual Reality

The details of the validity analysis results of the development of Case-Based Learning-based Virtual Reality (VR) are presented as follows to write Table 1.

Table 1. Percentage Of Validity Test Results For Virtual Reality Development

No.	Subject	Result	Qualification
1	Learning Content Expert Test	1 (Gregory's Validity)	Very High Validity
2	Learning Media Expert Test	95%	Very Good
3	Learning Design Expert Test	94.6%	Very Good
4	Individual Test	92.89%	Very Good
5	Small Group Test	93.04%	Very Good
6	Field Test	93.13%	Very Good

To assess students' responses to the implications of using virtual reality media, observations of student responses were conducted using a response questionnaire instrument through the Google Forms application. From the questionnaire distributed to a total of 32 students, 29 students reported that the use of Virtual Reality increased their motivation to learn mathematics, while 3 students stated that the use of Virtual Reality did not increase their motivation to learn mathematics. Student responses in the use of virtual reality for learning enthusiasm are show in Figure 6.
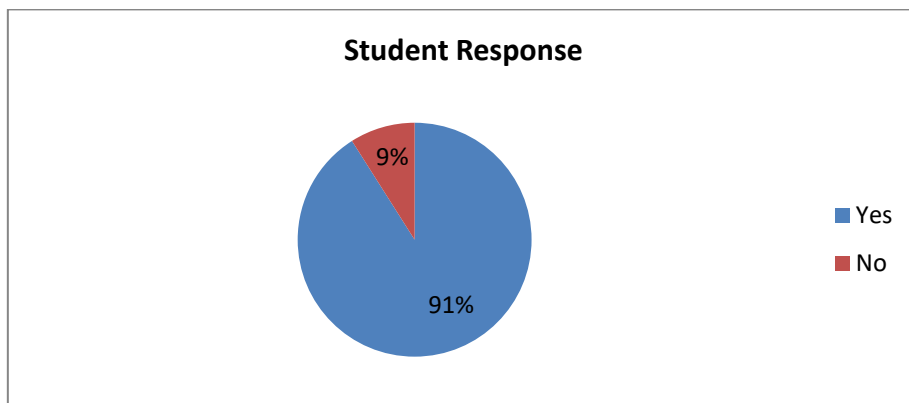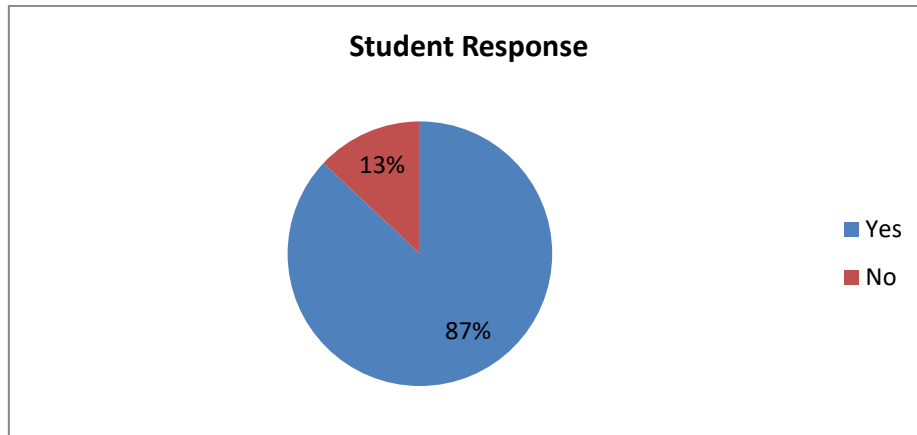

Figure 6. Student Responses in the Use of Virtual Reality for Learning Enthusiasm

From the questionnaire distributed to a total of 32 students, 27 students reported that the use of Virtual Reality reduced their fear in learning mathematics, while 5 students stated that the use of Virtual Reality did not reduce their fear in learning mathematics as show in Figure 7.
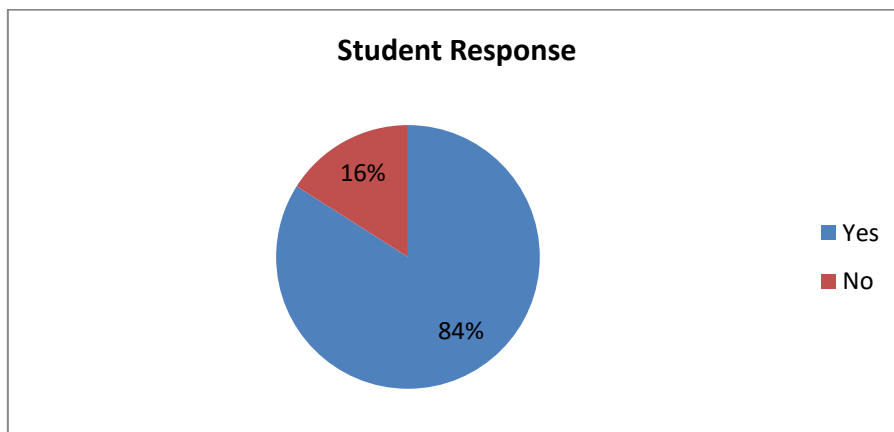
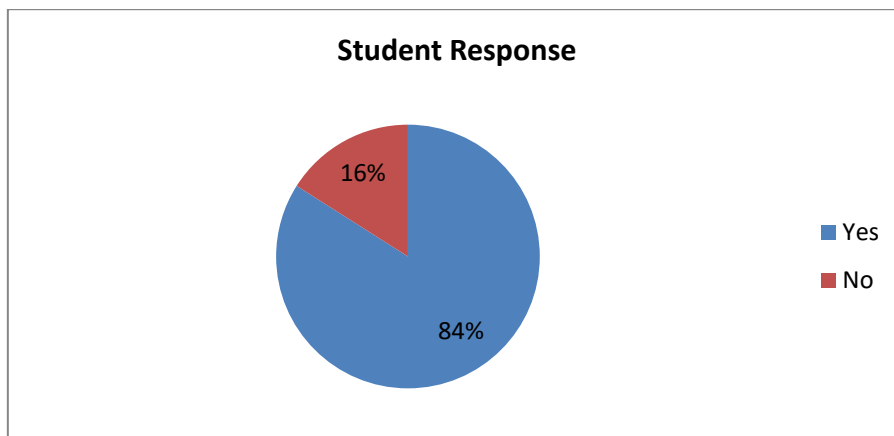**Figure 7.** Student Response in the Use of Virtual Reality Reduces Fear in Learning Mathematics

From the questionnaire distributed to a total of 32 students, 28 students reported that the use of Virtual Reality increased their confidence in learning mathematics, while 4 students stated that the use of Virtual Reality increased their confidence in learning mathematics. The result is show in Figure 8.

Figure 8. Student Response in the Use of Virtual Reality Increases Confidence in Learning Mathematics

From the questionnaire distributed to a total of 32 students, 27 students reported that the use of Virtual Reality increased their activity in learning, while 5 students stated that the use of Virtual Reality did not increase their activity in learning, as show in Figure 9.

Figure 9. Student Response in the Use of Virtual Reality Increases Learning Activities

The effectiveness of the development of Case-Based Learning-based Virtual Reality is implemented using a test method consisting of multiple-choice questions. The multiple-choice test questions are used to collect data on student learning outcomes before and after using virtual reality. The collection of student grades data aims to determine the effectiveness level of using case-based learning-based virtual reality in improving learning outcomes, which is done by using a correlated t-test for the sample. Before conducting the effectiveness test of the product, a test of the learning outcomes instrument and prerequisite test is carried out. The research hypothesis testing is performed using a t-test analysis with correlated subjects using the product moment formula and conducted at a significance level of 5%. The testing criteria are as follows: if the calculated significance value (2-tailed Sig.) is less than 0.05 (5% significance level), then H0 is rejected and Ha is accepted.

Based on the t-test calculation using SPSS, the obtained significance value in the Sig. (2-tailed) column is 0.000, which is smaller than 0.05 ($p > 0.05$). Therefore, H0 is rejected, and Ha is accepted. This result indicates a significant difference in learning outcomes and student performance before and after using Case-Based Learning-based Virtual Reality. Additionally, an N-Gain test was conducted to measure the extent of student understanding after using Case-Based Learning-based Virtual Reality. The calculated N-Gain score is 0.741, indicating a high category. This result shows that the use of Case-Based Learning-based Virtual Reality is effective in improving student learning outcomes in Mathematics for 8th-grade students at SMP Negeri 1 Negara.

Discussion

Design and development of case-based learning virtual reality is using the Dick and Carey development model. The selection of the Dick and Carey model is based on its orientation towards the development of learning products. The Dick and Carey model consists of 11 stages: (1) Needs analysis to determine goals, (2)

Identification of learning objectives, (3) Learning analysis, (4) Analysis of student characteristics and learning context, (5) Formulation of specific/performance objectives, (6) Development of learning strategies, (7) Development of criterion-referenced tests, (8) Selection and development of learning materials, (9) Design and implementation of formative evaluation, (10) Revision of learning media, and (11) Implementation of summative evaluation. The completed Virtual Reality draft is then presented to three experts, including a learning content expert from the Faculty of Mathematics at Ganesha Education University, a learning media expert from the postgraduate program at Ganesha Education University, and a learning design expert from the postgraduate program at Ganesha Education University. The content expert examines the entire learning material presented in virtual reality. The media expert assesses the visual aspects, images, and the presentation of 3D assets in virtual reality. The learning design expert evaluates the systematic structure of virtual reality and the learning process within it. These three experts provide input and suggestions to improve the virtual reality. The presence of these experts aims to validate the virtual reality as a viable learning product.

Based on the expert content review, it is stated that the content presented in the virtual reality aligns with the learning objectives, learning indicators, and learning goals. The content is presented in-depth and in an engaging manner, which motivates and interest students in the learning activities. In line with the expert review, a good learning media is one that aligns with the learning objectives in the curriculum and matches the characteristics of students in the learning process (Arif, 2018). Furthermore, the use of virtual reality has a significant impact on students' enjoyment and understanding of the taught material (Fardani, 2020; Hermawan et al., 2020). The experts' comments indicate a positive response to the content of the developed virtual reality with some notes for future improvements. Based on the expert learning design review, the delivery of material in virtual reality follows a logical learning sequence. It includes exercises aimed at understanding the material concepts, provides opportunities for independent learning, and has clear navigation. Learning with virtual reality creates a simulated environment using hardware and software, where students feel immersed and interact with the virtual objects (Fitrianto & Fahruddin, 2015; Oktafiani et al., 2020). The material presentation in virtual reality is clear, comprehensive, and aligned with the learning objectives. In line with this, a concise, compact, and clear presentation of learning materials supports students' understanding and effectively conveys the essence of the learning objectives (Putri et al., 2021; Susanti et al., 2018). The expert comments show a positive response to the design of the virtual reality, with some suggestions for future enhancements.

Based on the expert learning media review, it is stated that the virtual reality media adheres to the principles of message design, with appropriate and engaging visual, audio, and textual elements. The virtual reality can be effectively used through Android devices. Through interactive exploration in the virtual environment, students can receive and transmit planned messages, creating a conducive learning environment that allows for efficient and effective learning. Consistent with this, the appropriate design of messages in media provides students with a real experience in interpreting objects, facilitating clear understanding of the discussed objects (Munadi, 2013; Tegeh, I. M., Simamora, A. H., & Dwipayana, 2019). The expert comments indicate a positive response to the design of the virtual reality, with some suggestions for future improvements. The virtual reality draft, which was evaluated by experts, was then refined according to the given suggestions. It was then pilot-tested with 3 students classified as low-achieving, moderate-achieving, and high-achieving. The purpose of individual pilot testing was to ensure that the developed product could be used by students with varying levels of achievement in the learning process. The results obtained from the individual pilot testing showed good qualifications. Students' feedback stated that the virtual reality product is suitable for learning that requires visual/images in delivering the content. In line with these results, the components of virtual reality provide visual elements that cannot be directly presented in the classroom. Virtual reality can represent the imaginary world as it is in reality (Agusty, 2020; Subekti et al., 2021). Virtual reality applications can help provide an excellent visual overview based on aspects of software engineering and visual communication that are implemented in a virtual environment.

The small group testing consisted of 9 students with different levels of learning outcomes. Small group testing provides a broader validity value compared to individual testing. The students' responses in the small group testing were categorized as very good. Students commented that the virtual reality experience was excellent and motivating for learning mathematics. Consistent with these results, students' motivation to learn with virtual reality is higher compared to learning without any media or using conventional methods (Fardani, 2020; Tsaaqib et al., 2022). Learning with virtual reality enhances students' confidence in learning mathematics. Virtual reality-mediated mathematics learning, which is usually perceived as difficult by students, can influence their attitudes towards the learning process. Students with high self-confidence can manage the learning process well and develop independent learning skills (Pratiwi & Laksmiwati, 2016; Setiadewi et al., 2019). Field testing in virtual reality (VR) development is an important phase where user feedback helps refine the VR program. The results of field testing showed that students responded positively to learning with VR, finding it easier to understand and more enjoyable due to interactive games and animations. This aligns with previous research by Musril, suggesting that VR can address the limitations of traditional classroom learning by incorporating

engaging visuals and interactive elements to convey learning objectives effectively (Musril et al., 2020; Risma Handayani & Surya Abadi, 2020). Virtual reality provides an interactive experience that engages users in a virtual simulation environment. Based on the questionnaire responses, the use of virtual reality was found to increase students' enthusiasm for learning mathematics. Learning media allows for different approaches in presenting learning materials. By using various media such as videos, audios, graphics, and animations, students can actively engage in learning. This creates an interesting and stimulating environment, which in turn enhances their enthusiasm for learning more (Juniari & Putra, 2021; Paramita et al., 2022). Furthermore, the implementation of virtual reality was found to boost students' confidence in learning mathematics. This is supported by previous study who suggests that engaging and interactive learning media can provide a more involved learning experience for students (Aristiani, 2016). When students can follow and understand the learning materials through media such as videos, simulations, or games, they feel more confident in their understanding. Successful comprehension and use of such media boost their confidence in their learning abilities. Furthermore, the questionnaire results revealed that the implementation of virtual reality media makes students less afraid to participate in mathematics lessons, enabling them to absorb the material taught by the teacher. Through virtual reality, students can experience an immersive and engaging learning experience. They can interact with mathematical objects in a realistic virtual environment, such as manipulating geometric shapes or visualizing abstract mathematical concepts. This experience helps students feel more engaged and connected to the material, thereby reducing their fear of facing mathematics lessons (Darojat et al., 2022; Liu et al., 2018; Rusydiyah et al., 2020).

The implications of this research may indicate that the use of virtual reality is effective in learning Mathematics, especially for SPLDV material. This can be the basis for developing more interactive learning methods. Another implication is the potential for developing more sophisticated educational technology. The results of this research can encourage further development in the use of VR in education. However, this research has limitations, one of which is that the success of using VR in learning can greatly depend on the availability of VR technology. Not all schools or institutions may have adequate access to VR devices. Apart from that, several factors such as teacher ability, material design, and student motivation can also influence the effectiveness of using VR in Mathematics learning. It may be difficult for this study to separate all these variables.

4. CONCLUSION

A virtual reality (VR) program utilizing case-based learning was developed for eighth-grade mathematics. Following the Dick and Carey model and undergoing validation by experts, the VR program received high scores, indicating its suitability as an effective learning tool. Through individual, small group, and field testing, it was confirmed that the VR program significantly improved students' mathematics learning, as evidenced by the significant difference between pretest and posttest scores. The program's moderate effectiveness, as indicated by the N Gain value, along with students' positive response and improved outcomes, including increased motivation, enthusiasm, activity levels, self-confidence, and reduced fear of learning mathematics, highlight the VR program as a successful and valuable resource for both students and teachers.

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