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Development of Electropneumatic Simulation Learning Media based on Virtual Reality for Increasing Students' Competence Skills in Industrial Automation Engineering of Vocational School

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Abstract

This research and development aim to (1) know the development step of Electropneumatic simulation learning media based on Virtual Reality for increasing students' competence skills in Industrial Automation Engineering; (2) create a proper Electropneumatic simulation learning media based on Virtual Reality for increasing students' competence skill in Industrial Automation Engineering; (3) analyze the effectiveness level of Electropneumatic simulation learning media based on Virtual Reality for increasing students' competence skill and response in Industrial Automation Engineering. This research and development used the ADDIE model (Analyze, Design, Develop, Implement, Evaluate). The effectiveness level of virtual reality media was analyzed using n-gain data from the pre-test and post-test enhancement score results. The results of this research and development are as follows: (1) the developed virtual reality media worked well after passing the functional test by using the Black Box testing method; (2) the development of the Virtual Reality learning media received an average score of 87.77% from three media experts and an average score of 88.75% from two subject matter experts. Based on these average scores, virtual reality learning media is categorized as "VERY PROPER" and can be used as a learning medium for practicum; (3) the use of Virtual Reality was effective in increasing students' competence skills and response, based on the hypothesis testing results using a Paired Sample T-test, a Sig. (2-tailed) value of 0.129 > 0.05.The development research encountered several limitations, such as the high cost of Virtual Reality devices, students' unfamiliarity with Virtual Reality technology causing discomfort, and the extended time required for students to become proficient in operating Virtual Reality devices.

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INTRODUCTION

The advancement of technology has become a priority for all sectors [1], including educators, who must be adept at utilizing it to support the teaching and learning process [2]. The use of technology in education is essential for enhancing students' enthusiasm and interest in learning, making the learning process more interactive and engaging, makes educational media more innovative and effective. Teachers must continuously improve their professionalism following Law No. 14 of 2005 concerning teachers and Lecturers [3]. Educational media helps teachers manage the classroom, boost learning enthusiasm, and optimize student learning outcomes [4]. Integrating technology into the curriculum can create optimal and efficient learning [5][6]. The selection of educational media should consider factors such as specifications, cost, and ease of use [7]. The selection of media should be carefully planned to solve learning problems. In the era of Industry 4.0, technologies like Virtual Reality (VR) have become

popular [8]. VR can simulate interactive three-dimensional environments, helping to maintain learning focus and reduce distractions [9][10][11]. Virtual Reality can be effectively applied in education as it offers benefits and aims to enhance students' retention of information [12][13]. Utilizing Virtual Reality can transform subjects perceived as difficult and tedious by students into more imaginative and engaging experiences, especially when compared to traditional lecture-based teaching methods [14][15].

Vocational schools, especially in technical fields, often conduct practical work to enhance students' skills. [16][6]. Virtual Reality simulations can be effectively used in vocational education (SMK) due to the significant need for hands-on training and simulations. [17]. Virtual Reality can expand the scope of learning in vocational schools and increase students' focus, thereby improving their enthusiasm and motivation to learn [18][19][20]. Virtual Reality offers a unique capability to immerse its users as if they are in a specific environment, evoking the feeling of truly being there. This is expected to encourage users to actively participate in practical tasks without fear of being involved in hazardous situations, making the learning process more engaging and effective [21][22][23].

One of the common issues in the field of education is the lack of comprehensive practical facilities that mirror real-world industry conditions [22][24][25]. As a result, what is taught in schools often does not align with the practices in the industrial world. Vocational schools (SMK) located in rural areas or far from major cities often lack comprehensive practical facilities, making it difficult for them to conduct practical exercises using the latest tools or technologies relevant to the industry [26].

This situation also occurs at SMK Negeri 1 Cerme in the Industrial Automation Engineering concentration, specifically in the subject of electropneumatics. Some students still experience difficulties in conducting practical exercises. Several factors contributing to these difficulties include (1) students' limited understanding of the basic material; (2) lack of student interest in the demonstrations provided by the teacher; (3) incomplete practical equipment for the subject of Electropneumatic Control Systems; and (4) many components of the practical equipment for the Electropneumatic Control System subject are not yet aligned with the advancements in the business and industrial world in terms of both specifications and modernity. To address these issues, a modern learning media will be developed that can enhance interest and engagement and serve as a substitute for practical demonstration tools that the school currently lacks. The selection of Virtual Reality as the learning media is expected to be an appropriate alternative solution, as this technology can create realistic simulations resembling actual industrial conditions that are otherwise unattainable in the school environment. Additionally, this new technology is expected to increase students' interest, enthusiasm, and engagement in learning the Electropneumatic and Hydraulic Control System practicum [27]. The flexibility to create various objects, work scenarios, and work environments in Virtual Reality technology will be utilized and maximized to address the shortcomings in practical learning activities [28] at SMK Negeri 1 Cerme.

METHODS

The research method to be conducted by the researcher is the research and development (R&D) method, referring to the ADDIE development model by Branch [29][30]. The ADDIE model has five stages: (1) Analyze, (2) Design, (3) Develop, (4) Implement, and (5) Evaluate attached to each stage. The research process with the ADDIE model can be seen in Figure 1.

At the Analysis stage, several actions are taken, analyzing the basic needs of the research through direct observation and conducting interviews with teachers and students to collect relevant information regarding the problems and challenges that will later be discussed in this research. Design stage. Several actions taken in this stage include script writing, designing the concept of learning media and preparing the validation instruments for the learning media. Meanwhile, in the development stage, the actions taken include creating 3D objects, developing interactions and scenarios, conducting Functional Testing with the "Black Box Test" method, validating the learning media that has been developed with three

media experts (consisting of 2 lecturers from Universitas Negeri Yogyakarta and one vocational high school teacher) and two material experts (consisting of 1 lecturer from Universitas Negeri Yogyakarta and one vocational high school teacher), and revising the first product based on the validation results.

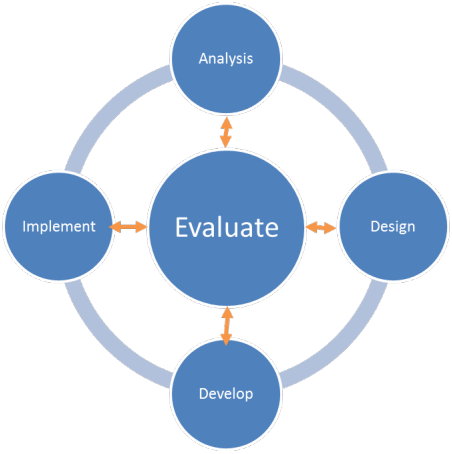

Figure 1. ADDIE stages

At the implementation stage, there are several actions taken, including conducting limited product trials to identify product deficiencies, conducting product revisions (second revision) based on limited product trials, conducting extensive product trials to assess the usefulness, feasibility, and effectiveness of Virtual Reality learning media, and finally analyzing research challenges from start to finish. The final stage is evaluation, which involves carrying out a comprehensive evaluation at each stage and addressing any deficiencies.

Research Subjects

This study also involved several research subjects, which included Media Validators, Material Validators, and Vocational High School (SMK) students from the Industrial Automation Engineering competency in Gresik Regency. Media Validators consist of two lecturers and one vocational high school teacher. They possess experience and expertise in designing and evaluating educational media, allowing them to provide credible feedback on the quality and effectiveness of the Virtual Reality media. Material Validators consist of one lecturer and one vocational high school teacher. They ensure that the content within the Virtual Reality learning media aligns with the curriculum and meets learning objectives, particularly in the field of Industrial Automation Engineering. Students from the Industrial Automation Engineering Competency. In Gresik Regency, there are only two vocational schools that offer the Industrial Automation Engineering competency, namely SMK Semen Gresik (where the researcher teaches) and SMK Negeri 1 Cerme. Based on the field observations conducted, SMK Semen Gresik is located in the center of Gresik City and is one of the vocational schools with fairly complete facilities and practical laboratories. It also has special access to various related industries, such as PT. Semen Indonesia, including in the Industrial Automation Engineering competency. Based on this data, SMK Semen Gresik was selected as the Control Group because the students from SMK Semen Gresik have more adequate skills and practical experience related to the Electropneumatic and Hydraulic Control System.

Meanwhile, SMK Negeri 1 Cerme is a school located quite far from the center of Gresik City. Its distance from the city center also limits the school's access to shopping centers and various related industries, resulting in obstacles and delays in fulfilling the needs for practical facilities and infrastructure due to lower mobility. Based on this data, SMK Negeri 1 Cerme was chosen as the Experimental Group. These students from the control group (SMK Semen Gresik) do not receive the treatment, meaning they are taught through conventional methods without the use of VR learning media. They serve as a comparison to assess the effectiveness of VR. These students from the experimental group (SMK Negeri 1 Cerme) receive the treatment in the form of VR learning media, allowing an

analysis of how VR impacts their learning outcomes compared to conventional methods. The key difference between the control and experimental groups lies in their learning methods, with the control group using traditional approaches while the experimental group utilizes VR, enabling the researcher to analyze the impact of VR technology on the learning process. Additionally, students in the experimental group may exhibit varying levels of comfort and skill with the technology, allowing for an analysis of how technical proficiency and technological readiness influence learning outcomes. Given that the research subjects from the Industrial Automation Engineering field require practical skills that are often difficult to develop in schools that lack adequate equipment, VR media offers a valuable solution by simulating real-world industrial environments, making it especially relevant for practical, hands-on learning. This is further emphasized by the fact that the students are studying technical competencies, underscoring the significance of VR technology in supporting this type of education.

Instruments and Data Collection Techniques

The data collection techniques in this study include observation, interviews, questionnaires, and tests. Observations are conducted to gather information that can serve as supporting data for the development of the Virtual Reality learning medium using an observation sheet as the instrument. Interviews are conducted to obtain direct information from the education practitioners involved in the study and verify the observations' results. The questionnaire is divided into four stages: functional testing, material validation, media validation, and user response. Functional testing employs the Black Box Testing method. Material validation is carried out to determine the validity level of the media based on the objectives of media use in learning and the content's relevance to the learning material. Media validation assesses the media's validity based on technical functionality, user safety, and system performance. User response collection aims to gauge students' reactions to the functionality of the Virtual Reality learning medium. The questionnaire is answered using a rating scale. The rating scale measures respondents' quantitative answers, utilizing a 4-point Likert scale (Table 1) with the following criteria: 1) Very Improper, 2) Improper, 3) Proper, 4) Very Proper. Tests are divided into two stages: pre-test and post-test, to determine the average gain in learning outcomes. The tests are conducted using a question sheet consisting of 20 items related to Electropneumatic and Hydraulic Control System materials.

Table 1. The criteria for the percentage score of VR media validation

Percentage	Criteria
81 % – 100 %	Very Proper
61 % - 80 %	Proper
41 % - 60 %	Improper
0 % - 40 %	Very Improper

Data Analysis Techniques

Data analysis techniques are employed to formulate and verify hypotheses, as well as to explore data and model development. [31][32]. In this study, two aspects of data need to be analyzed: (1) the validation results of the VR simulation media product and (2) the result analysis to prove the effect of the VR simulation media. The analysis techniques for the VR simulation media refer to the results of the questionnaire filled out by the material experts, VR media experts, and user responses from the students. The average questionnaire scores will be calculated as percentages using the following formula:

$$P = \frac{\Sigma R}{N} x100\% \quad \text{..... (1)}$$

Explanation:
P = Percentages score
ΣR = Total score obtained from the questionnaire
N = Maximum score of the questionnaire

The analysis of the effectiveness level of VR media as a learning medium can be seen from the gain value based on the mode, with the actual gain value obtained from students' test results. The gain formula is as follows:

$$g = \frac{Post - Pre}{Maks - Pre} \quad \text{..... (2)}$$

Explanation:
g = Obtained gain value
Pre = Pre-Test score
Post = Post-Test score
Maks = Maximum test score

Table 2. Gain value category [33]

Gain Value	Category
0.00 – 0.30	Low
0.31 – 0.70	Middle
0.71 – 1.00	High

The average gain data from the pre-test and post-test are used to test the research hypothesis. The hypothesis testing is analyzed using the paired Sample t-test because each group (control and experimental) represents two paired samples but with different locations and treatments. The hypotheses proposed in this study are:

H0 = There is no significant difference in test scores for the Electropneumatic and Hydraulic Control System subject between the control and experiment groups.

H1 = There is a significant difference in test scores for the Electropneumatic and Hydraulic Control System subject between the control and experiment groups.

H0 will be rejected, and H1 will be accepted if the Asymp. Sig. (2-tailed) value is smaller than the significance level of 0.05. The effectiveness of using VR as a learning medium can be determined by the gain value based on the mode, with the actual gain value derived from the students' test results.

RESULT AND DISCUSSION

The results of this development research are in the form of a learning medium in Virtual Reality for the subject of Electropneumatic and Hydraulic Control Systems, operated using the Oculus Quest 2 VR device. This research follows the ADDIE development model, with each step detailed as follows.

Analyze

This stage aims to collect preliminary data for the development of VR learning media to support the practical course on Electropneumatic and Hydraulic Control Systems in vocational schools. The analysis step involves the following activities: (1) Personal Observation, (2) Teacher Interviews, and (3)Student Interviews.

The research began with personal observations conducted at SMK Semen Gresik and SMK Negeri 1 Cerme. The observations included monitoring teachers, students, and the workshop environment. These activities were guided by an observation framework previously developed by the researcher, which covered several aspects, including (a) Curriculum and learning models, (b) Student behavior and interest, and (c) Workshop conditions and the availability of practical equipment. The observations revealed the continued dominance of conventional teaching models, low student interest in learning, and facility differences between the two schools

The Teacher interviews were conducted following several aspects, such as the current curriculum, teaching models used, teaching methods applied, learning media utilized, as well as challenges and learning difficulties that contributed to students' lack of enthusiasm. Some key findings from these interviews indicated that the curriculum, teaching models, and methods used were conventional, with only PowerPoint presentations and projectors being employed for delivering lessons. Additionally, the

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severe shortage of practical equipment was identified as the biggest obstacle in conducting practical activities, especially in the Electropneumatic and Hydraulic Control System subjects.

The student interviews covered the duration of lessons, learning interests, media, and practical activities. Key findings from the student interviews were summarized as follows: SMK Negeri 1 Cerme had very limited learning time due to the use of a conventional schedule, allowing practical activities only two days per week per class. This was in stark contrast to SMK Semen Gresik, where they had implemented a two-week block system for scheduling practical activities, resulting in significantly more practical time and better practical experience for students. Furthermore, the substantial difference in practical facilities between the two schools also played a role. Students from SMK Negeri 1 Cerme expressed that during the Electropneumatic Control System lessons, they had never conducted any practical activities, relying only on watching videos and performing simulations using the software. This impacted their practical experience, leading to a decrease in students' grasp of the practical material. To address the limitations observed in the practical learning of Electropneumatic and Hydraulic Control Systems, the development and implementation of Virtual Reality learning media are crucial. This solution aims to provide students with immersive, hands-on, practical experiences, regardless of the availability of physical equipment. Integrating VR into the curriculum can hopefully enhance students' understanding and engagement, equalize learning opportunities across schools with varying facilities, and ultimately improve the overall quality of vocational education.

Design

The design stage is divided into two steps: preparing the VR media script and preparing the media validation instruments. The researcher prepared the script for VR media development to address the challenges faced by teachers, the characteristics of the students, and the achievement of competencies. The preparation involved experts in Software Engineering and Game Development for input based on the previous analysis.

The researcher prepared research instruments in the form of questionnaires for media validation, material validation, functional testing (Black Box Testing), user responses, as well as pre-test and post-test questions. These instruments were based on a framework from the literature review and were validated by expert lecturers from the Faculty of Engineering, Universitas Negeri Yogyakarta. Validated instruments were used immediately, while those needing revisions were corrected based on expert suggestions. The instrument validation was considered "READY" with some improvements in answer options according to the Instrument validators.

Development

The Development stage includes the creation of VR media, functional testing, and the validation of both media and material. The researcher created 3D objects using "Sketch-Up" and "Blender" software, then integrated them using "Unity" to produce the VR program. The process of creating 3D objects can be seen in Figures 2 and Figure 3.

The VR media installed on Oculus Quest 2 underwent functional testing using the Black Box Testing method, involving Software Engineering and Game Development teachers. This test evaluated three aspects: visuals (Splash Screen, Main Menu, Help Menu, Title of the Material, Objective List), 3D objects, and audio (background and sound effects). Based on the results of the VR Media Functional Testing using the Black Box Testing method, all components were deemed "COMPATIBLE" with no errors, indicating that the VR Media functioned normally and was ready for use in the research.

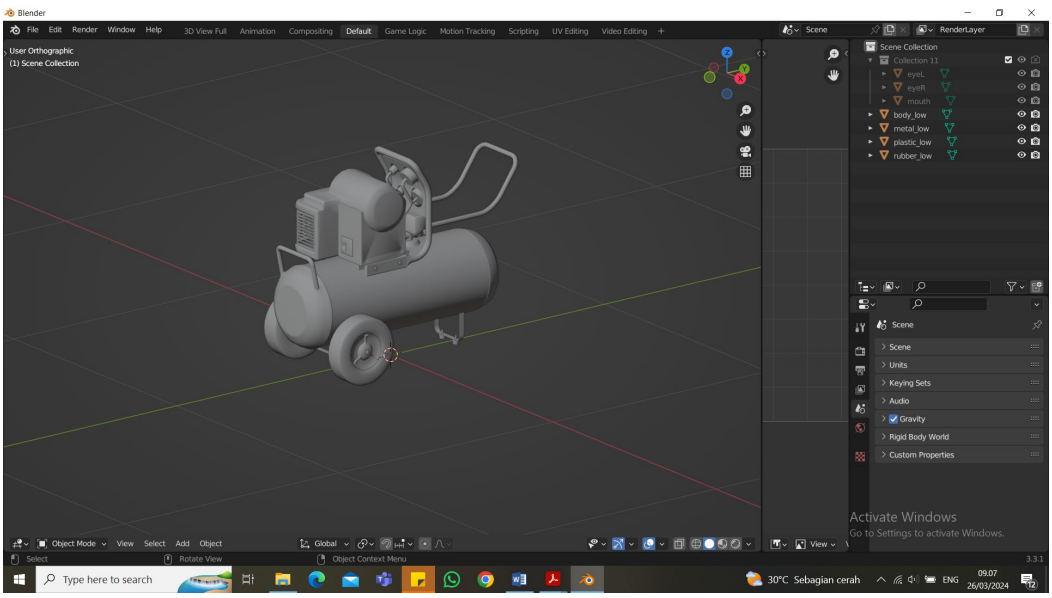

Figure 2. Created 3D object a Compressor

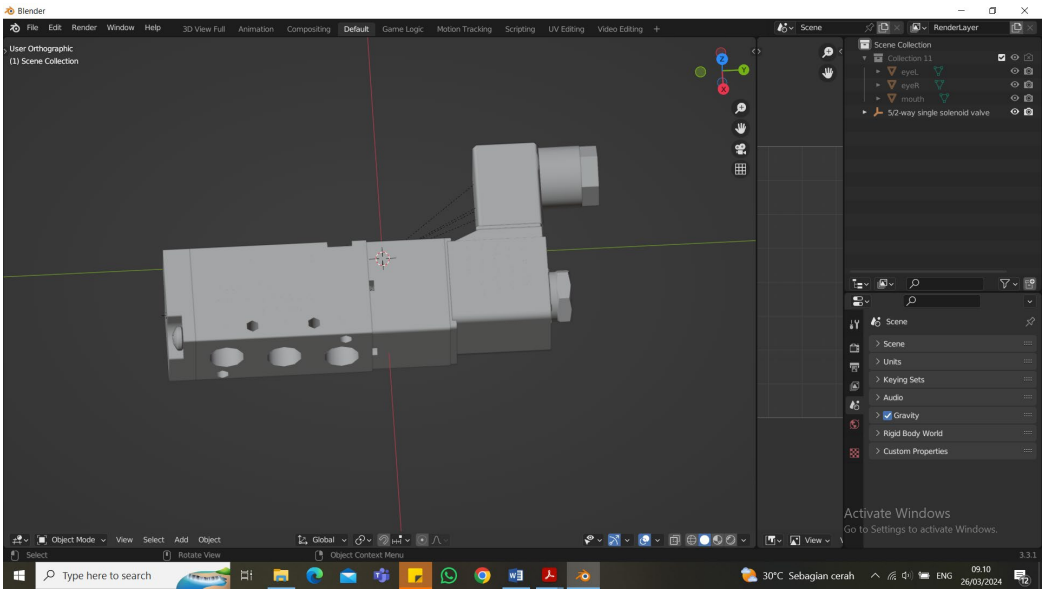

Figure 3. Created 3D object, a Solenoid Valve

The Virtual Reality media validation stage was carried out to assess its feasibility through two phases: media expert validation and material expert validation. Media expert validation involved two lecturers from Universitas Negeri Yogyakarta and one vocational school teacher knowledgeable in multimedia, while material expert validation involved one lecturer from Universitas Negeri Yogyakarta and one vocational school teacher who taught electropneumatics.

Table 3. Analysis of Media Expert Validation Result

Respondent	Average	Criteria
Respondent 1	80.83	Very Proper
Respondent 2	93.33	Very Proper
Respondent 3	89.16	Very Proper

Based on the validation results from three media experts, Respondent 1, a lecturer from Universitas Negeri Yogyakarta, gave an average score of 80.83, which falls under the “Very Proper” criteria. Respondent 2, also a lecturer from Universitas Negeri Yogyakarta, gave an average score of 93.33, also categorized as “Very Proper”. Respondent 3, a teacher from SMK Negeri 1 Cerme, gave an average score of 89.16, similarly classified as “Very Proper”.

The conclusion drawn from the media experts' validation indicates that the learning media VR-based is deemed "Very Proper" for use in practical learning activities. Several suggestions were provided to refine further the VR learning media product, including: (1) adding interaction in cable installation to allow it to be connected from two different sides, enhancing the user's cognitive skills, and (2) enriching the VR simulation environment with additional objects related to common hand tools found in the practical environment, to enhance the sense of realism.

Table 4. Analysis of Material Expert validation result

Respondent	Average	Criteria
Respondent 1	88.125	Very Proper
Respondent 2	89.375	Very Proper

Based on the validation results from two material experts, Respondent 1, a lecturer from Universitas Negeri Yogyakarta, gave an average score of 88.125, which falls under the "Very Proper" criteria. Respondent 2, a teacher from SMK Semen Gresik, gave an average score of 89.375, similarly classified as "Very Proper". The conclusion drawn from the material experts' validation indicates that the learning media is deemed "Very Proper" for use in practical learning activities. Several suggestions were provided to further refine the VR learning media product, including (1) adding a brief material section following the Learning Objectives in the Jobsheet within the Guidebook.

Implementation

The Virtual Reality media device that passed the validation stage will then be tested, implemented, and analyzed. Limited testing was conducted before the Virtual Reality media device was implemented to determine if there were any shortcomings or system weaknesses when operated. Based on the result of this limited usage test, involving six test subjects who provided descriptive comments and suggestions, all six subjects concluded that "The Virtual Reality media device functions well, is quite good, interesting, and advanced" for application. The implementation stage was conducted to obtain the average gain score of the students, which was then used to analyze the effectiveness of the Virtual Reality media device. This implementation stage was carried out in three sub-stages: 1) Pre-test, 2) Treatment, and 3) Post-test.

Based on the average Pre-Test result (Table 5) at both schools, it was found that SMK Semen Gresik, the control group, had a better average score than SMK Negeri 1 Cerme, the experimental group. This was because SMK Semen Gresik had far more complete practical equipment than SMK Negeri 1 Cerme, leading to significant differences in the students' competencies. This reason may also explain the low Pre-Test scores of the experimental group. As we know, SMK Negeri 1 Cerme does not yet have adequate practical equipment related to Electropneumatik and Hydraulic Control Systems, resulting in limited mastery and learning experiences for SMK Negeri 1 Cerme students in this subject.

The treatment activity was conducted after collecting the Pre-Test scores, which included explaining the competency objectives of the Electropneumatic and Hydraulic Control System material and demonstrating the use of the Virtual Reality device to the students. This activity was conducted at SMK Negeri 1 Cerme as the experimental group, while at SMK Semen Gresik as the control group, only regular practical learning was conducted.

Table 5. Average Pre-Test result

Group	Average	KKM Standard 70
Control	71/100	Above KKM
Experiment	48/100	Below KKM

Based on the average Post-Test results (Table 6) at both schools, it was found that the experimental group, SMK Negeri 1 Cerme, had a significantly improved average score compared to the previous Post-Test average, even surpassing the control group's average score, SMK Semen Gresik, which only slightly increased from the previous Pre-Test average.

Table 6. Average Post-Test result

Group	Average	KKM Standard 70
Control	78/100	Above KKM
Experiment	80/100	Above KKM

Competency improvement analysis was calculated based on the gain score obtained from the actual average scores received by the students through the Pre-Test and Post-Test. Based on the summary of the gain score analysis (Table 7), it can be seen that the gain score in the experimental group was higher than in the control group. The conclusion drawn indicates that the use of the Virtual Reality media device was able to enhance the students' vocational competency in the experimental group more effectively than in the control group, which did not use the Virtual Reality media device. A strong reason supporting this data is that, after the use of VR as a practical learning medium, students at SMK Negeri 1 Cerme finally understood the context of learning Electropneumatic and Hydraulic Control Systems, their enthusiasm increased, and the VR media provided a different atmosphere and learning style preventing students from feeling bored.

Table 7. Summary Table of Gain Score Calculation

Group	Average		*Gain*	Category
	Pre-Test	Post-Test		
Control	71/100	78/100	0.24	Low
Experiment	48/100	80/100	0.61	Middle

The summary of the user response analysis to the use of Virtual Reality media can be seen in Table 8. Based on the results from 35 respondents from the experimental group students, an average score of 87.279 with the "Very Proper" criteria was obtained for the VR media device in the Electropneumatic Control System. This indicated that the Virtual Reality media device is suitable and meets the students' expectations to increase their interest in learning the Electropneumatic and Hydraulic Control System competencies at Vocational High schools.

Table 8. Analysis of Average User Respons Results

Respondent Total	Average	Criteria
35 Students	87.279	Very Proper

Several students gave various responses after using the VR learning media. Some students reported feeling dizzy after using VR but found it very exciting to use. Other students found it difficult to interact because it was their first time experiencing VR technology. A few students mentioned having played VR before and felt challenged to try the practical activities within the VR environment. Overall, students were very enthusiastic and excited about the VR media, making the practical activities no longer boring. Additionally, students were able to experience what it feels like to practice in an industrial environment.

Figure 4. One of the students is using the VR learning media

The research hypothesis testing to determine the effectiveness of using the Virtual Reality media device to improve vocational competencies can be assessed through statistical calculations using the T-test. However, before the T-test is conducted, a prerequisite test must be performed. A normality test was conducted to determine whether the data was normally distributed. The normality test in this prerequisite used the Saphiro-Wilk test, as each class had fewer than 50 student samples. Based on the result of the Shapiro-Wilk Normality test using SPSS 27 software, the Sig. values were all above 0.05, indicating that all the student learning outcome data in all classes were normally distributed.

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelompok	Statistic	df	Sig.	Statistic	df	Sig.
Hasil Belajar	Pre - Kelas Kontrol	,257	16	,006	,901	16	,061
	Pre - Kelas Eksperimen	,202	33	,006	,891	33	,092
	Post - Kelas Kontrol	,324	16	,007	,831	16	,060
	Post - Kelas Eksperimen	,151	29	,007	,971	29	,072

a. Lilliefors Significance Correction

Figure 4. Normality test result

The next prerequisite test was the homogeneity test, which was conducted to determine whether the samples had the same variance. The homogeneity test used Pre-Test and Post-Test learning outcome data for each class.

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Hasil Belajar	Based on Mean	1,938	1	43	,129
	Based on Median	1,827	1	43	,148
	Based on Median and with adjusted df	1,827	1	33,515	,148
	Based on trimmed mean	1,961	1	43	,125

Figure 5. Homogeneity test result

Figure 5 shows the results of the homogeneity test. A significance value Based on Mean of 0.129 was obtained. Based on the criteria, the Sig. value of 0.129 > 0.05, indicating that all data were homogeneous or had the same variance.

The research hypothesis test was the final test conducted to prove whether the use of the Virtual Reality media device was effective in improving the vocational competency of Industrial Automation Engineering students.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Eksperimen_Post - Kontrol_Post	4.06250	12.67790	3.16948	-2.69308	10.81808	-1.282	15	.219

Figure 6. Paired Sample T-test result

Based on the hypothesis test results above, it was found that the sig. (2-tailed) value was 0.219 > 0.05; thus, it can be concluded that in this Paired Sample T-test, H0 was rejected, and H1 was accepted with the hypothesis statement, “There is a significant difference in test scores in the Electropneumatic and Hydraulic Control System subject between the control group and experimental group.”

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Evaluate

The evaluation stage serves as the conclusion, encompassing the entire process from Analysis to Implementation. The summary of the evaluation results is as follows: (1) Analysis Stage: The researcher encountered difficulties during interviews with students at SMK Negeri 1 Cerme because some answers were unclear and not credible, so assistance was requested from teachers to select capable students; (2) Design Stage: The researcher had difficulty creating a simple and appropriate Virtual Reality script and design, so advice was sought from Software Engineering teachers; (3) Development Stage: The researcher faced challenges in creating the Virtual Reality program due to a lack of coding expertise, so professional developer services were utilized; (4) Implementation Stage: All respondents were enthusiastic about using the Virtual Reality device, although some were still uncomfortable and unfamiliar with it.

Based on all stages, the Virtual Reality media device was deemed functional, suitable, and effective as a learning media to enhance the Industrial Automation Engineering competencies in the Electropneumatic and Hydraulic Control System.

CONCLUSION

This research produced Virtual Reality learning media for the Industrial Automation Engineering specialization at vocational schools (SMK), developed using the ADDIE model. The Virtual Reality media functioned well according to Black Box testing conducted by expert teachers in Engineering and Software, as well as a limited trial involving six 12th-grade students, who rated it as “VERY PROPER”. A broader trial also yielded a “VERY PROPER” rating, with the media successfully capturing students’ attention and enhancing their interest and motivation. The Virtual Reality media was deemed appropriate and ready for use in vocational schools based on validation by material and media experts, with an overall rating of “VERY PROPER”. This media proved effective for learning, as evidenced by improved student learning outcomes in the experimental group compared to the control group. A Paired Sample T-test analysis indicated an improvement in the Industrial Automation Engineering competence in the Elevtropneumatic and Hydraulic Control System subject.

Based on the conclusions regarding the product, the researcher offers the following suggestions: This research demonstrates that Virtual Reality can be an effective learning tool in vocational education, especially in the field of Industrial Automation Engineering. The integration of VR into learning can help address the limitations of physical facilities that often pose challenges in vocational schools, particularly for subjects that require expensive equipment such as electro-pneumatic and hydraulic control systems. VR allows practical simulations without the need for physical equipment, accelerating students’ comprehension and enhancing their engagement in learning activities. More broadly, this study highlights the potential of immersive and collaborative learning environments.

Educators and curriculum developers are advised to consider the use of VR as part of their instructional strategies, especially for subjects requiring extensive practical work, such as Industrial Automation Engineering. Educators can integrate this VR media into their syllabus by adapting the stages of practical learning. For effective implementation, teachers should receive proper training to optimize the use of VR, and user guides should be developed to ensure students can utilize the technology effectively. Curriculum developers should also design materials that align with the core competencies in this field, ensuring that VR serves as a relevant and appropriate teaching aid.

Several limitations to this study, such as: (1) not all schools have adequate VR devices, as they can be expensive and require robust technical infrastructure. (2) Teachers unfamiliar with technology may take longer to master its effective use. (3) Although VR is effective for practical simulations, some materials that require direct physical interaction still necessitate real-world practice. (4) Technical challenges such as latency or device limitations may also hinder the widespread implementation of VR.

In the future, further development of VR technology could focus on enhancing the realism of simulations and integrating with other technologies such as Virtual Reality (VR) and the Internet of Things (IoT) to create a more enriched practical learning ecosystem. This combination could enable

more complex and realistic industrial process simulations. Additionally, personalized learning with the assistance of artificial intelligence (AI) could allow students to receive learning experiences tailored to their skill levels. Further research could also examine how VR can be applied on a larger scale at a lower cost and its long-term impact on student learning outcomes in various fields of vocational education.

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