Developing Digital Teaching Materials with Augmented Reality-based 3D Virtual Laboratory for Vocational Teacher Candidates

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ABSTRACT

The challenges of the world of education are constantly evolving. The existence of digital technology that changes the perspective in learning patterns has a significant impact on creating interesting and up-to-date learning. The purpose of this research is to develop Digital Teaching Materials with Augmented Reality-Based 3D Virtual Laboratory for Prospective Vocational Teachers. This research is development research using 4D models, namely define, design, develop, and disseminate. This study involved 49 students of Mechanical Engineering Vocational Education who teach hydraulic and pneumatic courses. The development of digital teaching materials involves 3 media experts and 3 material experts. The instrument uses a product assessment questionnaire. Data analysis used descriptive statistics. The results show that the development of digital teaching materials on basic pneumatic system materials is very good theoretically with material expert assessment data of 3.39 in the very good category and media expert assessment of 3.55 in the very good category. The development of digital teaching materials on basic pneumatic system materials can theoretically provide new repertoire and experiences in developing teaching resources for lecturers and students.

Keywords: *Virtual Laboratory, Augmented Reality, Digital Teaching Material, Vocational.*

1. INTRODUCTION

The challenges of education are always evolving. Rapid technological developments in all sectors have both positive and negative impacts on these fields. This resulted in a shift in the pattern of education that used to use conventional methods to switch to the integration of technology in learning [1]. One of the reasons for the rapid development of technology today is the COVID-19 pandemic, which requires all lines of life to adapt. This has resulted in the rapid development of digital technology in various sectors.

The COVID-19 Pandemic incident has changed the order of human life as a whole, including the world of education. Face-to-face learning is transformed into virtual face-to-face learning as a whole for all levels of education, although this has previously been limited to the level of distance education in higher education [2]. This shows that education continues to develop to adapt to the demands and changing times which are always dynamic. The learning method developed requires teachers, students, infrastructure, management, culture and all elements in education to be ready to carry out an increasingly complex knowledge delivery process [3]. Therefore, the factors that influence learning success are important to pay attention to because they will affect the quality of learning.

Digital technology in learning is very important and is one of the elements that can support successful learning [4]. Online learning is carried out thoroughly both from the method of delivering materials, teaching materials, lesson plans, and other supporting activities in an integrated manner [5]. Many studies that have been conducted show the results that the integration of digital technology in learning has a positive impact on the achievement of student competencies [6]–[8]. This shows that the implementation of online learning and strengthening the learning process through digital technology is a combination of two very solute elements

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to solve and answer the challenges of the pandemic condition and the achievement of student competencies that can still be achieved.

Online learning requires adequate facilities and infrastructure. Learning media are needed that are easily accessible and used by students and are able to support online learning [9]. Learning facilities are indispensable for a quality teaching and learning process.[10].

One of the digital technologies that is developing in the world of education today is digital teaching materials to support the learning process [4] . Digital teaching materials can be in the form of online teaching materials or soft files, videos, or online assessment platforms that can help students achieve learning success [11] . Digital teaching materials have a very important role in the current learning process because the implementation of online learning requires all teachers to be ready to develop digital teaching materials according to the characteristics and needs of the subjects being taught. one of digital teaching materials is augmented reality. The techniques and media employed in the learning process have an impact on students' abilities [12]. The term "augmented reality" (AR) refers to a technology that attaches three-dimensional objects to the surface of a flat environment which is projecting virtual objects into a reality [13] . Users can view the real environment while using AR [14] . This shows that AR technology can be used for learning.

AR plays an important role in digital learning [15] . Today's digital technology must always be able to answer the challenges and needs of students. The existence of AR technology is one of the innovations that has a positive impact on improving the quality of sustainable learning. When compared to other technologies, augmented reality has numerous benefits, including: (1) being interactive, (2) being effective, (3) being simple to use across media, (4) depicting items simply, (5) being inexpensive, and (6) being simple to use [16] . AR can be a digital learning technology that can provide new experiences for students [17] . By superimposing virtual objects onto an agent's visual field, augmented reality (AR) technologies 'augment' normal perception [18].

Digital teaching materials in higher education are currently growing according to the demands and needs of courses. One of the courses in Vocational Education in Mechanical Engineering, Faculty of Teacher Training and Education at the Sultan Ageng Tirtayasa University, which is developing digital teaching materials, is the pneumatic hydraulics course. Based on the results of the interview, it is still necessary to develop digital teaching materials to add references and study materials, especially basic pneumatic materials. This is because students still have difficulty understanding the basic concepts of component functions and visualizing how components work. Based on these considerations, research is needed on the development of digital teaching materials on pneumatic system materials. Digital teaching materials developed based on the lesson plan for pneumatic hydraulics courses, especially on basic pneumatic materials.

2. METHOD

This research is a development research using 4D models, namely define, design, develop, and disseminate. The development of research products in the form of digital teaching materials on basic pneumatic system materials refers to the 4D development steps that have been adapted to the characteristics and needs of research. The location of the research was carried out in the Mechanical Engineering Vocational Education (PVTM) Faculty of Teacher Training and Education (FKIP) Sultan Ageng Tirtayasa University (Untirta). The research subjects were 49 PVTM students who taught hydraulics and pneumatics courses. The experts involved are 3 material experts and 3 media experts to measure the feasibility of the developed product.

Data collection techniques using interview techniques and questionnaires. Interview technique is used for preliminary studies looking for problems and uncovering conditions that occur so that they can find the basis for determining solutions. Questionnaire technique to analyze the feasibility of research products involving material experts and media experts. The research instrument was a list of questions and a validation questionnaire for material experts and media experts. Data analysis using descriptive statistics. Analysis of the validity of the data from the expert assessment using a Likert scale of 1-4 with the following criteria.

Table 1. Rating Scale.

Criteria	Score
Very Good	4
good	3
Less	2
Very Less	1

Calculation of the average score of each aspect with the formula:

$$x = \frac{1}{Number\ of\ validators} \text{ x } \frac{\sum_i^n x}{n} \qquad (!)$$

x = Average score of each aspect
$\sum_i^n x$ = Total score of each aspect
n = Number of items per aspect

Table 2. Assessment Classification Guidelines.

Interval			Category
Mi + 1,5	< X	Mi + 3 SD	Very Good/Very

SD	≤		High
Mi	< X ≤	Mi + 1,5 SD	Good/High
Mi - 1,5 SD	< X ≤	Mi	Less/Low
Mi - 3SD	≤ X ≤	Mi - 1,5 SD	Very Less/Very Low

Information:
SMi = ideal maximum score
Mi = ideal mean =1/2SMi
SDi = Ideal Standard Deviation = Mi/3

Table 3. Assessment Classification Guidelines.

Interval			Category
3,25	< X ≤	4	Very Good
2,5	< X ≤	3,25	good
1,75	< X ≤	2,5	Less
1	≤ X ≤	1,75	Very Less

3. RESULT AND DISCUSSION

The research procedure for developing digital teaching materials on basic pneumatic system materials uses a 4D model, namely define, design, develop, and disseminate. The following are the results of the research conducted.

3.1 Results

3.1.1 Define stage

The define stage is the first stage which aims to obtain initial information to define the condition of the problems faced by mechanical engineering vocational education students, especially in hydraulic and pneumatic courses. This stage consists of a front end analysis which aims to define the basic problem. This stage produces information that students have difficulty in understanding the material, especially basic pneumatic material. The methods and teaching materials used are still monotonous and innovation is needed to be developed better. Students have problems understanding the concepts and workings of pneumatic components.

The next step in the define stage is learner analysis. This step aims to analyze information from the front-end analysis stage and explore the problem more carefully, especially from the learner's perspective. Based on the results of the learner analysis study, the test scores for the hydraulic and pneumatic courses for the mid-semester exam are 71.63, and the final semester exam with an average of 74.02. The meaning behind this value after interviewing the students, it turns out that they still have difficulty in understanding the concept of function and how the components work. The next stage is concept analysis. This stage aims to analyze the learning resources used by lecturers for students. Based on the results of the study, it shows that the learning resources used are still limited to e-books which are still very global. In addition, the use of video and fluid simulator applications is not considered optimal to achieve the expected competencies.

The next stage is task analysis. This stage aims to analyze all matters relating to the assignments given to students. Based on the analysis that has been done, students get a task to make a series of pneumatic systems but they still find it difficult to understand quickly. The last step of the define stage is specifying instructional objectives. This step aims to summarize the define stage analysis process to determine what strategic solutions need to be done. Based on the results obtained, it is concluded that it is necessary to conduct a study on the development of digital teaching materials on basic pneumatic system materials for students taking hydraulic and pneumatic courses.

3.1.2 Design Stage

The design stage aims to design and design research products in the form of digital teaching materials on basic pneumatic system materials. The design stage consists of four steps, namely 1) Criterion-test construction to determine the construction of research criteria for developing digital teaching materials. 2) Media selection, namely determining the media to be developed based on the analysis that has been done previously. Based on the results of the analysis, it was determined that the research product to be developed was digital teaching material on basic pneumatic system materials. 3) Format selection, which is to determine the format that will be used in product development. The format used is the format of teaching materials or digital teaching modules used for teaching hydraulics and pneumatics courses, especially for basic pneumatic system materials. 4) Initial design, which aims to design in detail the product, which consists of an introduction Chapter I which contains information on competency standards, descriptions, timing, prerequisites, instructions for using the model, objectives, and diagnostic assessments. Chapter II is learning which consists of activity plans and learning activities.

3.1.3 Stages of development

This stage aims to produce products that have been planned in the design stage, namely digital teaching materials on basic pneumatic system materials. This stage consists of two stages, namely expert appraisal and development testing. Expert appraisal involves 3 media experts and 3 material experts. This stage aims to analyze the theoretical feasibility based on expert judgment.

Table 4. Results of Material Expert Assessment.

No	Rating Indicator		Average Score	%	Criteria
1	**Content Feasibility Aspect**				
	a	Material Compatibility with RPS	3,44	86%	Very good
	b	Material Accuracy	3,33	83%	Very good
	c	Material Update	3,33	83%	Very good
	d	Encourage Curiosity	3,33	83%	Very good
2	Aspects of Feasibility of Presentation				
	a	Presentation Technique	3,50	88%	Very good
	b	Presentation Support	3,25	81%	Very good
	c	Learning Presentation	3,50	88%	Very good
	d	Coherence and Coherence of Thoughts	3,33	83%	Very good
3	Contextual Reality				
	a	Contextual Reality	3,39	85%	Very good
Average			3,39	85%	**Very good**

The table above shows that the theoretical development of digital teaching materials based on the assessment of material experts, which is 3.39, is in the very good category. This shows that the research product in the form of digital teaching materials is theoretically feasible according to material experts. The following are the results of the media expert's assessment

Table 5. Media Expert Assessment Results.

No	Rating Indicator		Average Score	Percentage	Criteria
1	**Aspect of Feasibility of Graphics**				
	a	Module Size	3,66	96%	Very good
	b	Module Cover Design (Cover)	3,37	84%	Very good
	c	Module Layout	3,53	88%	Very good
	d	Indicator Layout	3,58	89%	Very good
	e	Use of Letters	3,33	83%	Very good
	f	Use of terms/Meaning	3,60	90%	Very good
2	**Language Eligibility Aspect**				
	a	straightforward	3,44	86%	Very good
	b	Communicative	3,83	95%	Very good
	c	Dialogic and Interactive	3,66	92%	Very good
	d	Conformity to the Development of Learners	3,50	87%	Very good
	e	Conformity with Language Rules	3,33	83%	Very good
	f	Use of terms, symbols or icons.	3,83	95%	Very good
Average			**3,55**	**89%**	Very good

The table above shows that the theoretical development of digital teaching materials based on the assessment of media experts, which is 3.55, is in the very good category. This shows that the research product in the form of digital teaching materials is theoretically feasible according to media experts.

This research was only carried out until the expert appraisal stage and had not yet entered the development testing stage to directly test user perceptions or assessments.

3.1.4 Disseminate Stage

The disseminate stage is the final stage of all research product development steps in the form of digital teaching materials on basic pneumatic system materials. The disseminate stage aims to publish or promote research products. In this research, the disseminate stage is in the form of printing digital textbooks and registering them with publishers to obtain ISBNs and participate in scientific activities.

3.2 Discussion

3.2.1 Product Development Steps

The step of developing research products in the form of digital teaching materials on basic pneumatic system materials using a 4D model (Thiagarajan, Semmel, & Semmel, 1974) which consists of stages (a) defining stage, (b) design, (c) development (develop), and (d) dissemination (desseminate). Development of digital teaching materials adapting and modifying 4D models to guide the development of research products. This is based on the consideration that the 4D model is

considered the most appropriate model for the development of the resulting digital teaching material.

3.2.2 Product eligibility

The research product developed is in the form of digital teaching material on basic pneumatic system materials. The research product development involves 3 material experts and 3 media experts whose task is to provide theoretical assessments of the technical quality of research products. Based on the results of the material expert's assessment, the research product in the form of digital teaching materials on basic pneumatic system materials is included in the very good category with a value of 3.39. This shows that the research product has a very good technical quality from the perspective of a material expert.

Based on media experts, the research product in the form of digital teaching materials is in the very good category with a score of 3.55. This shows that theoretically the research product in the form of digital teaching has very good feasibility from the perspective of media experts. The feasibility of the research product developed from the two types of assessments, namely media experts and material experts, both fall into the very good category. this shows that the research product has technical quality from the perspective of material experts and media experts. Research products can be used to add references to digital teaching materials on basic pneumatic system materials.

4. CONCLUSION

Based on the results of research and analysis that has been done. The conclusions of this study are as follows; 1) this research is a development research using a 4D model as its development step, namely define, design, develop, and disseminate. 2) the feasibility of research products based on the assessment of material experts, namely getting a score of 3.39 in the very good category, and media experts getting a score of 3.55 in the very good category. based on the media experts and material experts who have been involved, the research product theoretically has a very good feasibility from the perspective of media experts and materials experts. Digital teaching materials can be used to add references to basic pneumatic system materials.

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