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Development of Virtual Laboratory-based Learning Media on Sensor and Actuator Device Elements

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Abstract
Today's technological advancements can be used to suit the demands of many areas of life, including education. Technology in education enables more flexible medium for learning. Limited laboratory facilities in vocational high schools hamper practicum activities that are very important to achieve the standard competence. Virtual laboratory-based learning media is needed to simulate theory and practicum activities without time and place restrictions. This research aims to develop and calculate the feasibility of virtual laboratory-based learning media in the form of guidebooks and job sheets for sensor and actuator subjects using the Wokwi platform, arduino simulation projects, and sensors. This research uses the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) with data collection through observation, interviews, validation by media experts and material experts, and trials to students. Data were analyzed qualitatively and quantitatively. This study involving 77 students from class XI of Industrial Automation Engineering (*Teknik Otomasi Industri/TOI*) SMK PGRI Singosari showed results that the teaching materials achieved a combined validity value of 92.41% for the guidebook, 93.88% for the job sheet, and 93.20% for the Wokwi platform. The combined validity value ranges from 85.01% to 100% which indicates that the teaching materials are very valid and suitable for use. In conclusion, this virtual laboratory-based learning media supports the understanding of sensor and actuator subjects in vocational education. This learning media effectively overcomes the limitations of laboratory facilities while increasing student learning motivation.

Keywords: learning media, virtual laboratory, ADDIE, sensors and actuators

INTRODUCTION

In education, technology opens up innovations in learning more flexible media. Khakim et al., (2024) stated education providers are required to meet the needs related to the fulfillment of practicum materials and tools, which are the main components in the practicum model learning process. If learning media use traditional methods, the financing needed to meet these needs is very large if it does not follow technological developments (Sulistiani et al., 2023). Learning media is a tool that teachers use to convey information or messages to students during the learning process (Wulandari et al., 2023). The media can be printed, digital, visual, audio, or a combination of stated media. Students can access materials anytime and anywhere via mobile phones, computers, tablets, and online learning applications (Safitri et al., 2023). Using technology in the learning process also allows for simulations and learning through videos to facilitate understanding of complex material. Therefore, the development of technology improves the quality of learning and allows unlimited access to education in various conditions and region (Suyuti et al., 2023).

Vocational high school (*Sekolah Menengah Kejuruan/SMK*) primarily produce skilled workers based on industry needs in their chosen fields. Vocational education integrates theory and practice through activities such as practicums and internships in the industrial world (Nugroho et al., 2020). Vocational practicum requires laboratory facilities that support the vocational subjects taught to the students. If the facilities are not sufficient, the vocational schools may fail to reach their competence objectives (Rahmah & Rochmawati, 2023). Laboratories are places to carry out practical theory and practice activities that are not maximally fulfilled in theory classes. Laboratory activites help students to deepen their understanding of the subjects, improve study methods, and enrich their knowledge including the skills to maximize competency (Marpaung et al., 2021). However, there are still many vocational schools that have limited laboratory facilities, causing practicum activities to run ineffectively and have a negative impact on the achievement of student competencies.

Observations and interviews at SMK PGRI Singosari Malang Regency reveal several challenges in implementing the XI Industrial Automation Engineering (*Teknik Otomasi Industri/TOI*) class learning on sensor and actuator devices. First, the absence of job sheets hinders systematic guidance for students during practicum. Second, the direct use of tools without simulation increases the risk of damage to tools and components. Third, practicum activities only at school limit students' understanding of the material. Although emerging technologies such as virtual laboratories have great potential to overcome these limitations, their implementation in SMK is still minimal. Virtual laboratories are an innovative solution for online laboratory learning without physical facilities or time and place constraints but can still convey important concepts to students. Teachers' lack of knowledge of utilizing existing technology can slow down the development of effective learning media for students. The solution to the limitations of laboratory facilities is to develop virtual laboratory-based learning media that provides practicum to vocational students in a practicum that is easily accessed. Not only it provides flexibility in learning without time and place constraints, it also increases student motivation through an interactive approach based on modern technology and supports the understanding of sensor and actuator concepts by offering a safe and realistic practicum experience through virtual simulation.

This research develops guidebooks and job sheets for sensor and actuator devices courses as learning media. Guidebooks are teaching materials that contain information or

systematic instructions that help users to understand and perform activities independently (Limbong et al., 2022). A job sheet is a worksheet that contains instructions, work steps, tools, and materials used in practicum to assist students in doing practicum independently without direct teacher guidance (Erdi et al., 2022). This research uses the Wokwi platform, a web-based electronic simulator capable of virtually simulating Arduino devices, sensors, and actuators without hardware requirements. The ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model guides this research through stages that include needs analysis through observation and interviews, designing learning media concepts, product development, implementation by trials for student use, evaluation through expert validation, and revision according to trials and evaluations results (Ramadhani & Asrul, 2024).

This research offers an innovative solution for inadequate laboratory facilities while encouraging digital transformation in vocational education methods. The application of Wokwi as a microcontroller learning media based on a simulator shows its practicality in practicum implementation and improves students' hard skills (Suhaeb et al., 2024). In contrast to previous studies, this research emphasizes the development of a guidebook for using Wokwi from registration to completion of simulations equipped with job sheets according to the steps of sensor and actuator practicum adapted from the Wokwi website.

METHOD

The research and development model used by researchers in developing virtual laboratory-based learning media about sensor and actuator devices is the ADDIE development model. The ADDIE model consists of 5 stages: Analysis, Design, Development, Implementation, and Evaluation. The data collection techniques used are observation and interviews. Then the data are analyzed using validity tests with percentage calculations. The following are the stages of developing virtual laboratory-based learning media using the ADDIE model.

The first step in this research and development was to collect information about the problem in order to know what learning media was needed in the school. Information collection was done by direct observation and interviews with teachers. The second stage was designing the learning media according to the analysis of the learning media needed. The media design developed was then adjusted to the curriculum applied and compiled with the flow and learning objectives to fit with the learning guidelines. In this stage, the instrument assessment is also designed so that validation by validators can generate reliable data. The third stage was development, which elaborated on the previously adjusted design results and the product procurement in real form; at this stage, experts validated the product. The validators were teachers as material experts and lecturers as media experts. After the product had been validated and obtained reliable results or could be used without revisions, then the product was tested on students, which is the 4^{th} step. The trial in this development involved 77 students of class XI TOI SMKS PGRI Singosari.

The final stage was to conduct an evaluation. The evaluation method used was formative evaluation based on questionnaire filled by the students. Media and material experts were also involved in the evaluation process. Researchers used the assessment results from these experts and students to improve laboratory-based learning media products in the subject of sensor and actuator devices that had been developed. The data analysis method used included qualitative analysis to analyze experts' comments,

suggestions, and improvements, then the results were used to revise the under-developing learning media. Aftermore, quantitative analysis techniques were used to analyze scores from validation results, media feasibility questionnaires, and product trial questionnaires. The results were processed using a Likert scale with a range of 1-4 according to the categories of Table 1 and Table 2 using the formula:

$$P = \frac{Tse}{Tsh} x100\%$$

Where:
P = Percentage
Tse = Number of scores obtained
Tsh = Total maximum score

The formula is used to calculate the combined validity results then to decide whether the learning media was suitable for application.

$$V(\%) = \frac{Vah + Vuk + Vub}{3} x100\%$$

V = Combined Validation
Vah = Media Expert Validation
Vuk = Small Group Test Validation
Vub = Large Group Test Validation

Table 1. Likert scale guidelines

No.	Description	Score
1.	Very precise	4
2.	Quite right	3
3.	Less precise	2
4.	Very less precise	1

Table 2. Criteria for validity of teaching materials

No.	Aspect	Validity Level
1.	85.01% - 100.00%	Very valid or can be used without revision
2.	70.01% - 85.00%	Fairly valid or can be used but needs minor revisions
3.	50.01% - 70.00%	Less valid, recommended not to be used, needs major revisions
4.	01.00% - 50.00%	Not valid or should not be used

FINDINGS AND DISCUSSION

Findings

This research was carried out to overcome the limitations of laboratory facilities in SMK, increase learning motivation, and provide a better learning experience. In previous research, virtual laboratory-based learning media were developed, but only for analogue electronics material. Therefore, the researchers designed and created learning media for sensor and actuator devices. This research used the ADDIE model, with the following steps.

Analysis

At the analysis stage, data was collected before the research through observations and interviews with teachers at SMK PGRI Singosari, Malang Regency. This activity was carried out to find out the problems at the school in learning sensors and actuators. The main problem was that there was no Jobsheet used for practicum. In addition, no learning resource could be simulated in advance to reduce the risk of damage to tools and components. Moreover, the practicums that students carried out at school were limited by space and time. This resulted in students being unable to read the datasheet, so when doing direct practice, errors often occurred, which caused some components to be damaged. Therefore, learning media that could be simulated first were needed.

Design

The design stage was carried out by planning the determination of material, flow, and learning objectives. The materials used were temperature sensors, light sensors, distance sensors, PIR sensors, and pressure sensors. The learning media were designed with relevant and interesting colors and images so that students could be interested in participating in learning. In addition, designing product testing procedures was very important because it works as the guidance for the validation process. The final designs were then used for the development stage.

Development

The development stage was carried out by creating and modifying teaching materials according to the previous stage's results. At this stage, validation with experts was carried out. Product development in the form of a guidebook contained information on how to access and use the Wokwi platform and what menus could be used by Wokwi platform users during practicum. The difference between the teacher and student guidebooks lay in the menu that the respective users could access. This guidebook also explained the components used in the practicum of sensor and actuator devices. The structure of this guidebook consisted of (1) a cover, (2) a preface, (3) a table of contents, (4) a list of images, (5) an introduction, and (6) guidelines for using the Wokwi platform. The results of learning media development in the form of guidebook covers can be seen in Figure 1 and Figure 2.

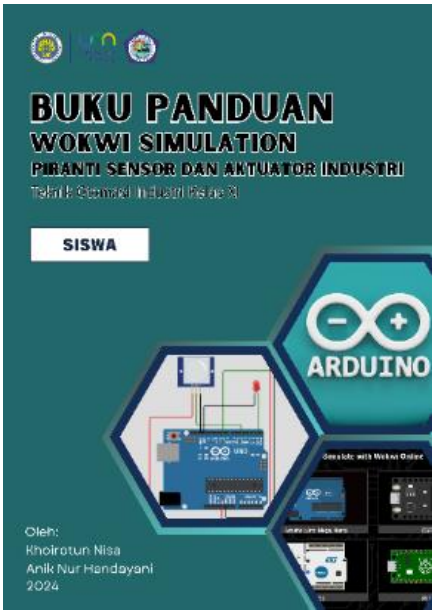

Figure 1. Student handbook design

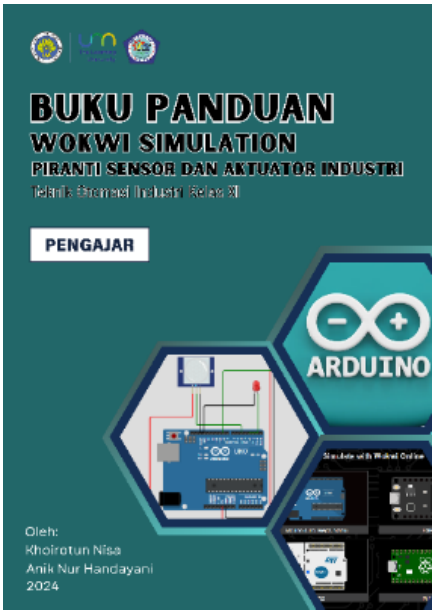

Figure 2 . Teacher's handbook design

The subsequent product development in this research was the job sheet. The developed job sheet had been adjusted to the flow, learning objectives, and curriculum used. The job sheet structure consisted of (1) cover, (2) preface, (3) table of contents, (4) introduction, and (5) contents of the job sheet with five practicums, namely (1) Jobsheet 1 Temperature Sensor Device (NTC) using LED as an actuator, (2) Jobsheet 2 Light Sensor Device (LDR) using LED as an actuator, (3) Jobsheet 3 Distance Sensor Device (Ultrasonic) using a Buzzer as an actuator, (4) Jobsheet 4 PIR Sensor Device using a Stepper Motor as an actuator, and (5) Jobsheet 5 Pressure Sensor Device (Load Cell) using a Servo Motor as an actuator. The job sheet structure was further divided into several sections consisting of (1) cover, (2) objectives, (3) theoretical basis, (4) tools and materials, (5) experimental steps, (6) simulation results, (7) analysis, (8) conclusions, and (9) bibliography. The results of learning media development in the form of Jobsheet covers can be seen in Figure 3 and Figure 4.

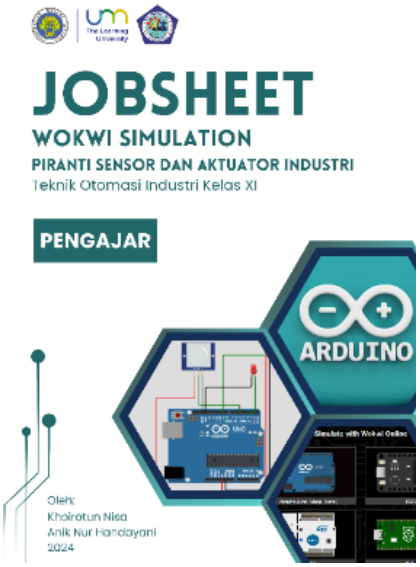

Figure 3. Teacher's Jobsheet design

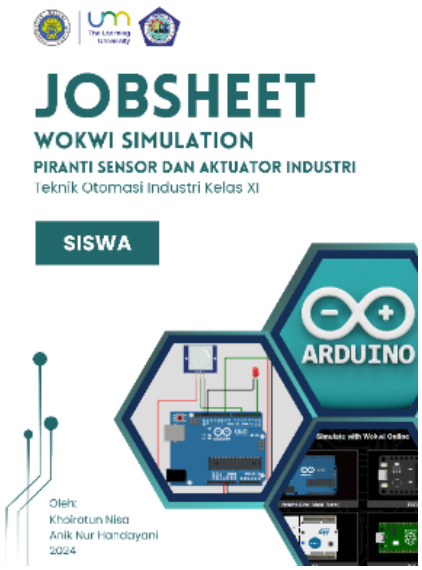

Figure 4. Student Jobsheet design

After the learning media development was completed. Through this validation, researchers received suggestions and criticisms of the teaching materials developed. The following data were obtained based on the material expert validation in Table 3, the teacher Jobsheet in Table 4, and the student Jobsheet in Table 5.

Table 3. Results of guidebook validation by material experts

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Feasibility of materials	1,2,3	12	12	100.00%	Very Valid
2.	Completeness	4,5,6,7,8	18	20	90.00%	Very Valid
3.	Ability to teach materials	9,10,11	12	12	100.00%	Very Valid
4.	Presentation	12,13,14,15,16,17	22	24	91.66%	Very Valid
5.	Language and visuals	18,19,20,21,22,23,24	27	28	96.42%	Very Valid
Total			91	96	94.79%	Very Valid

The results of the material expert validation for the guidebook for using the Wokwi platform in Table 3 show a total percentage of 94.79%, so that the guidebook could be continued to be tested on students.

Table 4. Results of teacher Jobsheet validation by material experts

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Feasibility and accuracy of materials	1,2,3,4,5	20	20	100.00%	Very Valid
2.	Completeness	6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20,21	61	64	95.31%	Very Valid
3.	Ability to teach materials	22,23	7	8	87.50%	Very Valid
4.	Presentation	24,25,26,27,28,29	22	24	91.66%	Very Valid
5.	Language and visuals	30,31,32,33,34,35,36	26	28	92.85%	Very Valid
Total			136	144	94.73%	Very Valid

The results of the material expert validation on the teacher's Jobsheet of sensor and actuator device elements based on Virtual Lab using the Wokwi platform in Table 4 show a total percentage of 94.73%. This value is in the very valid category so that the teacher's worksheet can be used as a guide for the teacher.

Table 5. Results of student Jobsheet validation by material experts

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Feasibility and accuracy of materials	1,2,3,4,5,6	23	24	95.83%	Very Valid
2.	Completeness	7,8,9,10,11,12,13,14, 15,16,17,18,19,20,21	58	60	96.66%	Very Valid
3.	Ability to teach materials	22,23	7	8	87.50%	Very Valid
4.	Presentation	24,25,26,27,28,29	23	24	95.83%	Very Valid
5.	Language and visuals	30,31,32,33,34,35,36	27	28	96.42%	Very Valid
Total			138	144	95.83%	Very Valid

The results of the material expert validation for the Virtual Lab-based sensor and actuator device material student job sheet using the Wokwi platform in Table 5, show a result of 95.83% which is included in the very valid category, so that the next job sheet can be tested on students to determine the level of feasibility. Furthermore, validation was carried out by media experts. The validation results are as follows.

Table 6.Guidebook validation results by media experts

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Media capability	1,2,3,4,5	20	20	100.00%	Very Valid
2.	Cover design	6,7,8,9,10,11,12,13,14	33	36	91.66%	Very Valid
3.	Content design	15,16,17,18,19,20,21,22	28	32	87.50%	Very Valid
Total			81	88	92.04%	Very Valid

The results of the media expert validation of the guidebook using the Wokwi platform in Table 6 show a total percentage of 92.04%, and the value is included in the very valid category, so that the guidebook can be used. Because in terms of design and content the guidebook is considered interesting and can improve the learning process.

Table 7. Results of Jobsheet validation by media experts

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Media capability	1,2,3,4	14	16	87.50%	Very Valid
2.	Cover design	5,6,7,8,9,10,11,12,13	34	36	94.44%	Very Valid
3.	Content design	14,15,16,17,18,19,20, 21	30	32	93.75%	Very Valid
Total			78	84	92.85%	Very Valid

The media expert validation results for the Virtual Lab-based sensor and actuator device element Jobsheet using the wokwi platform in Table 7 show a total percentage of 92.04% and the percentage is included in the very valid category so that the Jobsheet can be tested on students. The Jobsheet is considered to have an attractive design so that it can help the learning process effectively.

Table 8. Results of validation of the use of supporting platforms by media experts

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Support platform capabilities	1,2,3,4	16	16	100.00%	Very Valid
2.	Visual communication	5,6	7	8	87.50%	Very Valid
3.	Efficiency	7,8	8	8	100.00%	Very Valid
Total			31	32	96.87%	Very Valid

Table 8 show a total percentage of 96.87% which is included in the very valid category, so that the Wokwi platform can be used to support the practicum of sensor and actuator devices and can then be tested on students. After the development stage is complete and validation of the experts is found to be very valid or can be used without revision, it will proceed to the next stage, namely implementation.

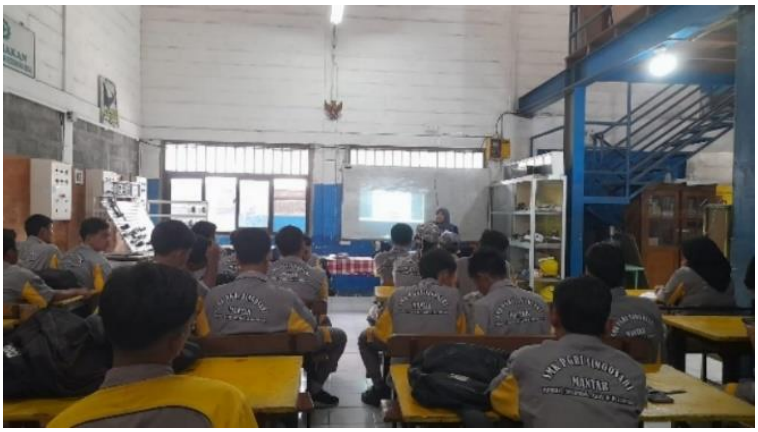

Figure 5. Implementation Stage for Students

Implementation

After carrying out the development stage and obtaining the results of learning media that were feasible for students in learning sensor and actuator device material, the implementation stage was carried out so that students could test in the actual learning process. The trial involved XI TOI class students of SMK PGRI Singosari, with 77 students, which was then divided into small group and big group. Small groups tested the readability of the product. While the big group, consisted by the other 67 students to test the feasibility of the products. Small group trials were conducted on 10 students using simple random sampling techniques so that respondents had the same opportunity. Respondents were selected by drawing lots. Researchers made 77 lottery papers, ten of which had numbers 1-10 written, while the rest were blank papers. Students who got papers with numbers were then included in the small group.

Table 9. Small group test results of the student handbook

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Capability of teaching materials	1,2,3,4	146	160	91.25%	Very Valid
2.	Completeness	5,6,7,8	146	160	91.25%	Very Valid
3.	Presentation	9,10,11,12	142	160	88.75%	Very Valid
4.	Language and visual	13,14,15,16,17, 18,19,20,21	335	360	93.05%	Very Valid
Total			769	840	91.54%	Very Valid

The results of the Small Group student trial of the guidebook using the Wokwi platform in Table 9, with aspects of Capability of teaching materials, Completeness, Presentation, Language, and Visual, showed a total percentage of 91.54%, which was included in the category of very valid or feasible to use.

Table 10. Small group test results of student Jobsheet

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Capability of teaching materials	1,2,3,4,5	181	200	90.50%	Very Valid
2.	Completeness	6,7,8, 9,10	183	200	91.50%	Very Valid
3.	Presentation	11,12,13,14	145	160	90.63%	Very Valid
4.	Language and visual	15,16,17,18, 19,20,21,22,23	329	360	91.39%	Very Valid
Total			838	920	91.10%	Very Valid

The results of the small group student trials of the Virtual Lab-based sensor and actuator device student Jobsheet using the Wokwi platform in Table 10, on several aspects, namely Capability of teaching materials, Completeness, Presentation, Language, and Visual, showed a total percentage of 91.10%, which was included in the very valid category.

Table 11: Wokwi Platform Small Group Test Results

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Supporting platform capabilities	1,2,3,4	145	160	90.62%	Very Valid
2.	Visual communication	5,6	74	80	90.00%	Very Valid
3.	Efficiency	7,8	77	80	96.25%	Very Valid
Total			296	320	92.50%	Very Valid

The results of the small group student trial of the supporting platform in Table 11, with several aspects, namely supporting platform capabilities, Visual communication, and Efficiency, showed a percentage of 92.50%, so the platform as a supporting platform was suitable or feasible for use in the practicum of sensor and actuator device subjects. Meanwhile, in the large group student trials, the following data were obtained.

Table 12. Large group test results of the student handbook

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Capability of teaching materials	1,2,3,4	989	1072	92.25%	Very Valid
2.	Completeness	5,6,7,8	991	1072	92.44%	Very Valid
3.	Presentation	9,10,11,12	982	1072	91.60%	Very Valid
4.	Language and visual	13,14,15,16,17, 18,19,20,21	2236	2412	92.70%	Very Valid
Total			5198	5628	92.35%	Very Valid

The results of the large group student trial of the student guidebook using the Wokwi platform in Table 12 showed a total percentage of 92.35%, with aspects of Capability of teaching materials, Completeness, Presentation, and Language and Visual included in the category of very valid or very suitable for use.

Table 13. Large group test results student Jobsheet

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Capability of teaching materials	1,2,3,4,5	1242	1340	92.68%	Very Valid
2.	Completeness	6,7,8, 9,10	1227	1340	91.56%	Very Valid
3.	Presentation	11,12,13,14	981	1072	91.51%	Very Valid
4.	Language and visual	15,16,17,18, 19,20,21,22,23	2224	2412	92.20%	Very Valid
Total			5674	6164	92.05%	Very Valid

The results of the large group student trial of the virtual lab-based sensor and actuator device student Jobsheet using the Wokwi platform in Table 13 showed a total percentage of 92.05%, with several aspects of Capability of teaching materials, Completeness, Presentation, and Language and Visual included in the category of very valid or very feasible to use.

Table 14. Wokwi platform large group test results

No.	Aspect	Indicator	Score		Percentage	Description
			Tse	Tsh		
1.	Supporting platform capabilities	1,2,3,4	989	1072	92.25%	Very Valid
2.	Visual communication	5,6	500	536	93.28%	Very Valid
3.	Efficiency	7,8	506	536	94.40%	Very Valid
Total			1995	2144	93.05%	Very Valid

The results of the large group student trial using the Wokwi website support platform showed a percentage of 93.05%, as shown in the table, with several aspects of

supporting platform capabilities, visual communication, and efficiency that were used in the practicum of sensor and actuator devices.

Teaching material products in the form of guidebooks and Jobsheets passed all stages of testing. Furthermore, the calculation of combined validity was carried out to determine the feasibility of learning media. Expert validation, small group tests, and large group tests for guidebooks on combined validity results obtained the following results.

$$V(\%) = \frac{92.04+91.54+92.35}{3} x100\% = 91.97\ \%$$

As for the validity of the Jobsheet results, the percentage obtained was as follows:

$$V(\%) = \frac{92.85+91.10+92.05}{3} x100\% = 92.00\ \%$$

The results of the two percentages fell into the criteria of very valid or very feasible, so they could be used without revision for virtual lab-based learning media in sensor and actuator devices. The percentage of combined validity results from using the Wokwi platform as a supporting platform was calculated as follows.

$$V(\%) = \frac{96.87+92.50+93.05}{3} x100\% = 94.14\ \%$$

The result indicated that the platform was valid or feasible to support the sensor and actuator device practicum. At this implementation stage, the material expert validation result calculation showed 94.79% for the guidebook, 94.73% for the teacher's job sheet, and 95.83% for the student job sheet. The combined validity result of the guidebook was 91.97%, and for the Jobsheet, it was 92.00%. Since the percentage results fell between 85.01% - 100.00%, this indicated that the teaching materials were valid or suitable for use in class XI TOI SMK PGRI Singosari. The combined percentage of the Wokwi platform assessment was 94.14%, making it suitable to support the practicum of Sensor and Actuator Device elements. With these data calculation results, the development of virtual laboratory-based learning media was feasible and could be applied to the learning of sensor and actuator device subjects.

Evaluation

Based on the data obtained through expert validation, product trials, and the results of the feasibility of learning media, it can be concluded that Virtual Laboratory-based learning media on learning elements of Sensor and Actuator Devices can be applied and can overcome the problem of limited laboratory infrastructure. This can increase learning motivation and provide a better learning experience for students in class XI TOI SMK PGRI Singosari. This statement was based on the fact that during the application of virtual laboratory-based learning media, learning went better because students could work together with fellow students for practicum, and students were more responsive in providing feedback to each other on the learning media innovations developed. This research allowed teachers to utilize existing technology for more flexible learning media.

Discussion

This research described previous research on developing and implementing virtual lab-based learning media using the Wokwi platform for vocational students. This research was conducted using the ADDIE model, and the results revealed several

important aspects related to the feasibility and implementation of virtual laboratory-based learning media for vocational students.

The result of calculating the guidebook's combined validity was 91.97%. The Jobsheet validity was 92.00%, and the percentage results ranged between 85.01% and 100.00%. This showed that the teaching materials were very valid or suitable for use as teaching materials. The combined percentage of the Wokwi platform assessment was 94.14%, so the platform was determined to be feasible to support the learning practicum of Sensor and Actuator Devices. With these data calculations, the development of virtual laboratory-based learning media was considered feasible and could be applied to the learning of sensor and actuator device subjects. Virtual lab-based learning media increased student motivation to understand sensor and actuator device subjects. This was in line with the research of Arrahman et al., (2023), which showed the use of virtual laboratory-based media in learning and that the media was suitable for use as learning tools, because the virtual laboratory developed met the eligibility requirements, including validity and effectiveness. The virtual laboratory was a medium that created a real interactive environment. In virtual laboratories, students could perform simulation experiments because they were very practical and could help students before doing the actual practicum.

The developed learning media attracted students' attention and encouraged them to be more actively involved in learning (Sofi'atun et al., 2024). This increased engagement was facilitated by interactive features that made students more active, allowed them to receive immediate feedback, and enabled them to learn through practical activities online that felt real. Research conducted by Permana et al. (2024) stated that learning media designed with attractive visuals helped students focus their attention during the learning process, which increased student motivation and participation in learning activities. Feedback from students and Teachers was very positive, with many stating that it was beneficial for learning and made students more active.

Based on the research that was done and some previous research, it could be concluded that the development of virtual laboratory-based learning media helped increase students' understanding and motivation to learn in the subject of sensor and actuator devices. There were differences from existing research, namely that the virtual laboratory learning media developed was the final result of teaching materials in the form of .pdf, which made it easier for teachers and students to access the learning media online and offline.

CONCLUSION

Based on research and development of Virtual Laboratory-based Learning Media on Sensor and Actuator device subjects with the ADDIE model (Analyze, Design, Develop, Implementation, Evaluation), the analysis stage is carried out to identify problems that occur in learning. The design stage is conducted to design the development; the development stage involves developing teaching materials and validating experts. The implementation stage evaluates the teaching materials on small and large groups. The evaluation stage is performed internally and externally to collect feedback on the products developed. The products are in the form of Wokwi platform guidebooks and job sheets for sensor and actuator subjects for teachers and students in .pdf documents, so that students and teachers can easily access them. The results of the combined validity percentage on teacher and student guidebooks, job sheets, and the Wokwi support platform are very valid or feasible for use. This signals that research and development of

virtual lab-based learning media using the Wokwi platform address the limitations of educational facilities and teaching materials and can be applied to the practicum of sensor and actuator devices. In future research studies, in addition to calculating feasibility, researchers can calculate the effectiveness of the product to determine the extent to which the research product's contributions improve student learning outcomes.

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