Development of Embedded System Learning Module
Using Project-based Learning Method for Industrial Electronics Department

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Abstract
The problem faced in the Industrial Electronics Department of Vocational High School (*Sekolah Menengah Kejuruan/SMK)* PGRI 3 Malang is the unavailability of systematic teaching materials in the learning process of embedded systems. The module is one of the teaching materials used to improve students' quality and produce independent and creative students. This research aims to develop Embedded System Learning Module using Project-based Learning method to overcome the urgent need for teaching materials. The research methodology used is R&D with the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation. The steps of developing this module include: 1) Analysis: identifying the needs of teaching materials; 2) Design: designing the elements needed in the learning module; 3) Development: making and validating the module by material and media experts; 4) Implementation: Small and large group trials in class XI of the Industrial Electronics department of SMK PGRI 3 Malang; 5) Evaluate: module feasibility analysis. Data collection in this study used interviews, observations, and questionnaire instruments. Product validation results were obtained from media experts, with a percentage of 87.5% (very valid), and material experts, with a rate of 95% (very valid). After the developed product received feasible criteria from the experts, a small group trial (10 students) and a large group trial (24 students) were conducted. The results of the small group trial were 85.7% (very valid), and the results of the large group trial were 87.8% (very valid). Therefore, this module is feasible for teaching material in learning embedded systems.

Keyword: Learning module, embedded system, ADDIE, project-based learning

INTRODUCTION

Vocational High School (*Sekolah Menengah Kejuruan/SMK*) is an educational unit that concentrates on specific fields of expertise to produce competent human resources as technical personnel in the industry according to their fields. The learning process in SMK integrates theory and practice as a form of application of the concepts that have been learned. The success of learning is highly dependent on the teaching materials used. Teaching materials used in the learning process, if developed as needed and utilized appropriately, can improve the quality of learning and education (Magdalena et al., 2021). One of the Vocational High Schools that is committed to producing quality and competence of graduates is SMK PGRI 3 Malang. This school is a private vocational high school in Malang with a concentration of electrical expertise consisting of four majors: Industrial Electronics Engineering, Power Plant Engineering, Industrial Chemical Engineering, and Audio and Video Engineering. The Industrial Electronics Department focuses on learning about electrical components and various types of semiconductor devices. Several things are studied, including Embedded Systems, Interfaces, and Serial Communication (Ramadhani et al., 2022). The Embedded Systems subject has several Learning Outcomes that must be mastered by students, such as students being able to evaluate embedded system architecture, design minimum systems, apply programming languages, operate compiler software, operate simulator software, create digital input/output programming, create analog input/output programming, and apply serial communication programming.

There are several problems with the implementation of embedded system learning. From the results of a brief interview with the teacher in charge of the embedded system subject of the Industrial Electronics Department of SMK PGRI 3 Malang, it was found that until now, no unique teaching material has been used to learn embedded systems. Teachers still rely on online learning resources and videos using media such as PowerPoint and Jobsheet. In addition, the learning process has not been carried out optimally because the scheduling system is still unstructured. This shows an urgent need for teaching materials that are more systematic and to student needs. Teaching materials are learning media that are important in the learning process. The teaching materials used in the Industrial Electronics Department of SMK PGRI 3 Malang are still conventional, and the learning process is still teacher-centered, so students cannot learn independently and have creative thinking. This is undoubtedly contrary to the demands of the 21st century to develop critical and creative abilities (Sari, 2023). To improve the quality of students and produce independent and creative students, innovative teaching materials are needed in the learning process (Iklina & Fadilah, 2022). Modules are one of the teaching materials used in the learning process. Students can use modules to learn independently or in groups. In addition, modules can also be used as evaluation tools and reference sources in learning (Novianto et al., 2018).

One of the efforts to develop students' creativity in learning is by implementing a Project-based Learning method on modules. Project-based Learning has six learning syntaxes, including (1) project selection, (2) planning of steps to complete the project, (3) preparation of a project implementation schedule, (4) project implementation with guidance and monitoring from the teacher, (5) preparation of a report or presentation of project results, and (6) project evaluation (Anggraini & Wulandari, 2020). Based on Mustika (2022) revealed that developing e-modules can improve students' creative thinking skills by applying the Project-based Learning method. In addition, this is also reinforced by observations made by researchers in the Teaching Assistance program that

students tend to be more active when applying Project-based Learning method compared to conventional learning models, such as lectures.

In supporting Project-based Learning that involves students actively at every stage of education, Learner Worksheets are needed to guide the project's completion (Adella & Dwi, 2023). The availability of Learner Worksheets in the Embedded Systems Learning Module can assist students in improving practical understanding. Students can integrate conceptual understanding through the theoretical basis or material presented in the module with actual application through project implementation. This is certainly in line with the concept of vocational literacy, which teaches students not only to understand the theory behind specific jobs but also to apply that knowledge in daily work (Rahmadani et al., 2023).

From the above background, the author is interested in conducting research about the development a learning module by using Project-based Learning method. It is expected to significantly impact enriching teaching materials that are innovative and in accordance with student needs, especially in the Industrial Electronics Department. In addition, with this module, students are expected to learn actively, independently, and creatively. They can develop practical skills to create Vocational High School graduates who are competent and ready to face the challenges of an increasingly complex world of work.

METHOD

The type of research used is research and development. The research and development method produces certain products (Sugiyono, 2018). This research designed a product, the Embedded Systems Learning Module that was used as a companion to existing learning resources. The ADDIE approach model developed by Branch (2009) was used in this module, which consists of 5 stages: Analysis, Design, Development, Implementation, and Evaluation. Data in this study were collected through interviews, observations, and validation questionnaires. Interviews were conducted to discover the problems and needs of the Industrial Electronics Department of SMK PGRI 3 Malang. Meanwhile, observations were made to determine the students' conditions, facilities, and infrastructure in this department. In conducting validity tests, questionnaires must be distributed to assess the feasibility level of the products developed.

The questionnaire instrument used in this study was taken from media experts, material experts, and XI-grade students majoring in industrial electronics at SMK PGRI 3 Malang with 20 questions each. Questionnaires given to media experts are assessed based on Technical Quality Aspect. Questionnaires given to material experts are evaluated based on Content Aspect and Learning Aspect. Meanwhile, the questionnaire given to students as users was assessed based on Language Aspect, Presentation Aspect, and Graphic Aspect. The types of data obtained from filling out this questionnaire are qualitative data and quantitative data. Qualitative data is obtained from suggestions and comments from expert validators and user responses. Quantitative data is obtained by filling out and assessing the questionnaire using a 4-level Likert scale, as seen in Table 1. The selection of 4 alternative answers is intended to prevent the selection of a middle (neutral) category answer (Riduwan, 2012). Furthermore, the quantitative data was analyzed to calculate the percentage of results from filling out the questionnaire. The percentage of results was used to determine the product's feasibility criteria based on the Table 2.

The formula used in calculating the percentage is:

$$Persentase\ (\%)\ = \frac{\sum R}{N}\ x\ 100\%$$

Source: (Puspita et al., 2024)

Explanation:

P = Percentage score (rounded result)

$\sum R$ = Total score count

N = Ideal score count

Table 1. Questionnaire assessment criteria

Category	Value Weight
Strongly Agree	4
Agree	3
Disagree	2
Strongly Disagree	1

Source: (Mulyatiningsih, 2011)

Table 2.Validity level

Validity Criteria	Validity/feasibility level
85,01% - 100,00%	Very Feasible (can be used without revision)
70,01% - 85,00%	Feasible (can be used with minor revisions)
50,01% - 70,00%	Less Feasible (recommended not to use need major revisions)
25,00% - 50,00%	Not Feasible (cannot be used)

Source: (Akbar, 2017)

FINDINGS AND DISCUSSION
Findings

Researchers chose the ADDIE approach model for several reasons, namely: (1) This model has a systematic and transparent workflow, (2) At each stage, revisions and evaluations are carried out based on the stages passed so that the resulting module becomes a product that is used, and (3) This model can be adapted to various models, learning strategies, media and teaching materials (Mulyatiningsih, 2011). The following is a description of the product development process based on the ADDIE stages.

Figure 1. ADDIE Model

Analyze

The action taken at this stage is to interview one of the embedded system Industrial Electronics subject teachers at SMK PGRI 3 Malang. From the results of these interviews, several problems were found that occurred during the implementation of learning, namely the absence of teaching materials that support students in learning independently and creatively, students only get material provided by the teacher through power points, videos, and the internet so that students only depend on the teacher (teacher-centred), and embedded system material in schools is still not systematically arranged with scheduling that is still messy.

Based on the problems that have been found, relevant and structured teaching materials are needed to support the learning process and can facilitate students in understanding embedded system material. The next step is to set goals. The goal is to develop an embedded system learning module using a Project-based Learning model for industrial electronics majors. This module is given to students at stage F, namely class XI students majoring in industrial electronics at SMK PGRI 3 Malang.

Before developing the learning module, researchers and teachers held discussions about the material to be used in the learning module. By the learning objectives and the flow of learning objectives that researchers obtained from the embedded system teacher of SMK PGRI 3 Malang, the material that researchers used in the learning module consists of embedded system architecture consisting of three flow of learning objectives, designing a minimum system composed of two flow of learning objectives, and applying programming languages comprised of one flow of learning objectives. This module presents the material in 3 chapters of learning activities.

From the observations made by researchers in the industrial electronics department of SMK PGRI 3 Malang, one of the facilities available at this school is a tablet and internet network used in the learning process. With supporting facilities and the advice of the embedded system teacher, the developed module is in the form of a soft file in pdf format.

Design

At the product design stage, researchers design modules that was developed based on the learning objectives to be achieved by students. The resulting product is a soft file in .pdf format with B5 paper size. Students can access the learning module offline through a smartphone device by downloading the module file or online through the internet network with the link provided. At this stage, the module components and feasibility test instruments were designed. The main components of the module include materials, practice questions, evaluation sheets, student worksheets, and scheduling. In the feasibility test instrument, an assessment sheet was designed as a questionnaire for media experts, material experts, and users. However, this design is still temporary because it underwent further development and improvement in the future based on suggestions and comments from experts and users. The following are the design results of several module parts, which can be seen in Figures 2, 3, and 4.

Figure 2. Module Front and Back Cover

The front cover contains the title of the module, the subject matter, the year of production, the author's name, images that represent the module's material, and the relevant institution's logo. The back cover contains a description of the developed module.
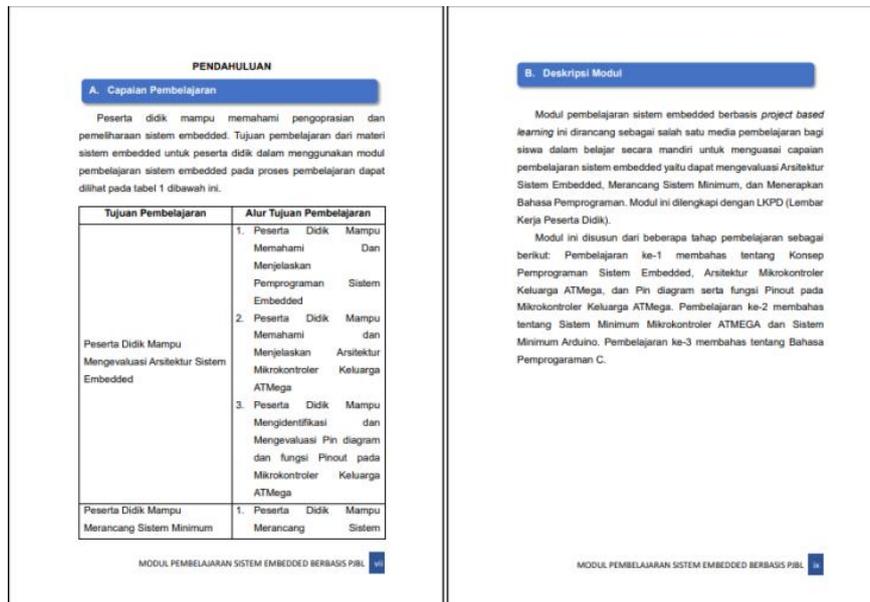

Figure 3. Module Introduction

In the introduction, there are several sections, namely learning outcomes consisting of three learning objectives, module description, explanation of Project-based Learning stages, concept map or learning material structure, instructions for using the module, learning agenda, and assessment guide.
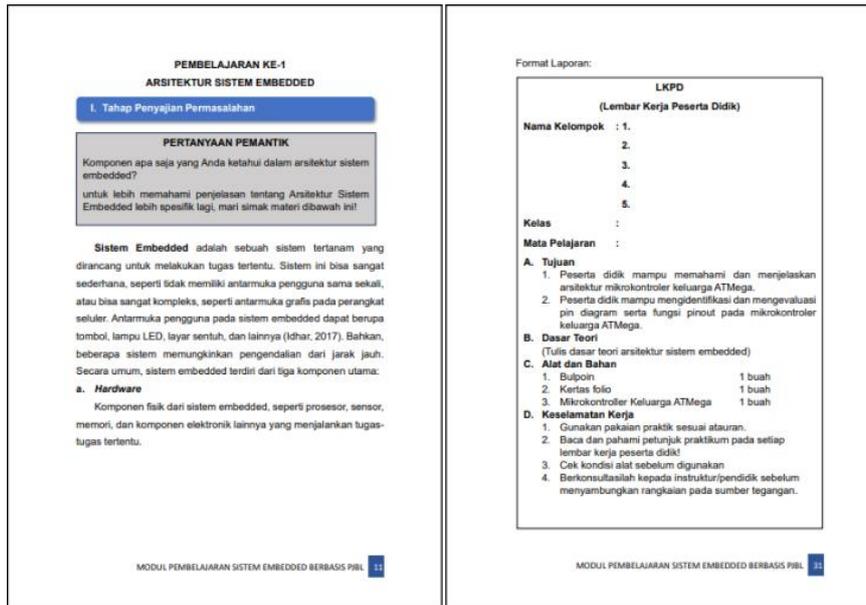
Figure 4. Module Learning Activities

In this module, the learning activities have three chapters, such as the first learning activity, which discusses embedded system architecture; learning activity two, which discusses minimum system design; and learning activity three, which discusses the application of programming languages. Each learning activity has several stages in accordance with the syntax of Project-based Learning , consisting of (1) the problem presentation stage contains trigger questions, material, and practice questions, (2) the planning stage contains guidelines for completing project tasks and Learner Worksheets, (3) the scheduling stage contains details of activities during the learning process, (4) the project monitoring stage contains a monitoring sheet that must be filled in by students so that the teacher can check the implementation of the project, (5) the assessment stage contains an assessment sheet with several aspects of assessment, (6) the evaluation stage contains a reflection stage carried out after going through all the stages above.

Development

The development stage is the implementation stage of the design. At this stage, the module has been designed to be a product that is ready to be presented to expert validators to test its validity. A validity test by experts aims to assess the feasibility of learning modules in terms of media and material before being implemented by students. In the media validity test, the media expert validator who was determined in this study is a lecturer in the Department of Electrical Engineering, Faculty of Engineering, State University of Malang (UM), who has extensive expertise and experience in the field of electrical engineering and learning media development. In the material validity test, the material expert validator who was determined as a content tester on the learning module is the teacher of the Embedded Systems subject, Industrial Electronics Department of SMK PGRI 3 Malang.

This study used a questionnaire as an assessment and data collection instrument. Aspects and indicators of the questionnaire were taken from expert theories. Walker and Hess' theory in Arsyad (2007) was used in the media expert questionnaire to assess the feasibility of the module from the technical quality aspect, while the material expert questionnaire added from Akbar (2017) to assess the feasibility of the content aspect and

learning aspect. The following is quantitative data that has been processed by researchers from filling out and assessing questionnaires by experts.

Table 3. Media expert validation

Indikator	Question Number	Empiric Total Score	Expected Total Score	Total (%)	Description
Readability	1-5	18	20	90	Very Feasible
Usage	6-9	14	16	87,5	Very Feasible
Display	10-16	24	28	85,7	Very Feasible
Module Management Quality	17-19	10	12	83,3	Feasible
Quality of Documentation	20	4	4	100	Very Feasible
Total		70	80	87,5	

Table 4. Material expert validation

Indikator	Question Number	Empiric Total Score	Expected Total Score	Total (%)	Description
Accuracy	1-3	11	12	91,6	Very Feasible
Balance	4	4	4	100	Very Feasible
Importance	5	4	4	100	Very Feasible
Completeness	6-8	11	12	91,6	Feasible
Interest/Attention	9	4	4	100	Very Feasible
Systematic presentation	10	4	4	100	Very Feasible
Motivation Quality	11-12	7	8	87,5	Very Feasible
Teacher and Learning Impact	13	4	4	100	Very Feasible
Student Impact	14-15	7	8	87,5	Very Feasible
Learning Support	16-18	12	12	100	Very Feasible
Learning Demands	19-20	8	8	100	Very Feasible
Total		76	80	95	

Implementation

At the implementation stage, user trials were carried out to determine student responses to the modules that had been developed. User trials were carried out in two phases, namely small group trials and large group trials. The small group trial was aimed

at 10 students in class XI Industrial Electronics using a simple random sampling technique to give respondents the same opportunity (Sugiyono, 2018). The small group trial aimed to identify initial problems so that revisions could be made to the module. After that, a large group trial was conducted aimed at 24 students of class XI Industrial Electronics to determine whether the developed module was suitable for use and applied to the learning process. The instrument used in the user trial was a questionnaire with aspects and indicators taken from the Walker and Hess theory in Arsyad (2007). There are several aspects of assessment in the user trial, including linguistic, presentation, and graphical aspects. Coordinating with teachers and students was carried out to collect data for the user trial questionnaire so that the module implementation ran smoothly. The data collection mechanism at the implementation stage begins with explaining the module to students. Then, students can observe and carry out learning activities using the module, and finally, researchers guide students in filling out the user trial questionnaire. The following is quantitative data that researchers have processed from students' results filling out and assessing questionnaires.

Table 5. Small group tests

Aspect	Question Number	Empiric Total Score	Expected Total Score	Total (%)	Description
Linguistic Aspect	1-4	130	160	81,2	Feasible
Presentation Aspect	5-9	152	200	76	Feasible
Graphic Aspect	10-20	404	440	91,8	Very Feasible
Total		686	800	85,7	

Table 6. Large group tests

Aspect	Question Number	Empiric Total Score	Expected Total Score	Total (%)	Description
Linguistic Aspect	1-4	141	160	88,1	Feasible
Presentation Aspect	5-9	160	200	80	Feasible
Graphic Aspect	10-20	402	440	91,3	Very Feasible
Total		703	800	87,8	

Evaluation

Data analysis is obtained from validation tests by media experts, material experts, and students as users at this stage. This data analysis aims to assess and evaluate how much the feasibility level of the product developed. The product is feasible if the validity level has a minimum score of >70.00%. Each question item on the indicator must get a score with a minimum criterion of 3 so that the product developed has "feasible" criteria. The following summarises the data from expert validation tests and user trial results.

Table 7. Validity test results

Validation Test	Percentage of validity (%)	Criteria
Media Expert Test	87,5	Very Feasible
Material Expert Test	95	Very Feasible
Small Group Test	85,7	Very Feasible
Large Group Test	87,8	Very Feasible
Average	89	Very Feasible

Discussion

In Table 3, the results of the validity test by media experts on technical quality aspects consisting of indicators of readability, use, display, and documentation get a percentage > 85% with eligibility criteria in each indicator, namely "very feasible", while the module management quality indicator receives a rate of 83.3% with eligibility criteria, namely "feasible". So, the average percentage of validity by media experts is 87.5%. It can be decided that the learning module is "very feasible" in terms of media. This shows that the product developed has fulfilled several principles of learning media development, namely Visible, Interesting, Simple, Useful, Accurate, Legitimate, and Structured (Wijayanti et al., 2022). However, some suggestions and comments were obtained from media experts on the indicators of readability, appearance, and quality of module management. First, media experts commented on the use of too many fonts so that the appearance of the module is less consistent and confusing for users. Second, some spelling and punctuation errors reduce the clarity of the information conveyed, so mistakes like this can affect students' understanding of the material being studied. Third, media experts also noted the use of paragraph spacing that was too far apart, making the text look fragmented and reducing the aesthetic impression of the module. Finally, the layout of the module is considered too dense, so the information seems piled up and is difficult for users to read comfortably.

Based on the suggestions and comments given by the media experts, the researchers made some improvements. To overcome the problem of using too many fonts, the researcher replaced the overall font with a more straightforward and more uncomplicated font, Arial. The font selection was done by considering the clarity and visual uniformity throughout the module content. Furthermore, the researcher corrected sentences that had improper punctuation and corrected spelling errors. This process was carried out by re-checking each page of the module to ensure that no mistakes were missed. In addition, researchers also improved the use of spacing in paragraphs. If the space used was previously 1.5, then after improvement, the space was changed to 1.0 so that the text looks neater and not too far apart. The last step taken is to improve the module layout by changing the margins on the module. This change was made to provide more proportional space on each page of the module so that the information does not look too dense and still comfortable to read.

In Table 4, the results of the validity test by material experts on the content aspect, which consists of indicators of accuracy, balance, importance, completeness, interest/attention, and systematic presentation, get a percentage> 85% with an average rate of validity of 97.2%. So that the eligibility criteria in the content aspect are "very

feasible". The learning aspect consists of indicators of motivational quality, impact on teachers and learning, student impact, learning support, and learning demands, getting a percentage> 85% with an average percentage validity of 95%. So that the eligibility criteria in the learning aspect are "very feasible". Overall, the validity test by material experts obtained a validation percentage of 96%. This shows that the developed module is in accordance with KI, KD, the needs of students, the need for media, the addition of knowledge for students, the truth of the content and the suitability must be with the applicable curriculum (Depdiknas, 2008). However, there are some notes by the material expert on the content aspect of the balance indicator, completeness, and systematic presentation. Some suggestions and comments from the material experts include simplifying the language used in the module to make it easier for students to understand, adding practice questions that are relevant to the learning context, adding pictures on specific topics, and reducing material that is considered too complex for the level of learning.

As a follow-up to these suggestions and comments, the researcher simplified some parts of the material by replacing technical terms that were difficult to understand with more straightforward language without reducing the essence of the material. Problem exercises were also added to provide opportunities for students to practice and understand the concepts of the material being taught. On specific topics, pictures were added to increase visual understanding and not make students too lazy to read. In addition, some parts of the material that were considered too complex by the material expert were broken down into smaller subtopics to make it easier for students to understand.

From the data described in Tables 3 and 4, it can be summarized that the percentage results of validation from media experts are 87.5% and validation from material experts is 96%, so the average percentage of experts is 91.7%. The developed module is included in the "very feasible" category because it gets a score above >85% so that the module can be applied and tested by students. In trial, researchers directed students to use the module during the learning process. The average percentage result of the small group test was 85.7%, with details, namely the Language Aspect getting a percentage of 81.2%, the Presentation Aspect getting a percentage of 76%, and the Graphics Aspect getting a percentage of 91.8%. Based on the eligibility criteria, the module was declared "very valid" because it received a score above > 85%, so there was no need for too many revisions to the module.

Furthermore, a large group test was conducted using data from Table 8. The average percentage result of the large group test was 87.8%, with details, namely, the Language Aspect received a percentage of 88.1%, so this aspect was declared "very feasible". This shows that the sentences used in this module are good, clear, communicative, and do not confuse so that students easily understand the material contained in this module (Delyana et al., 2021). The Presentation aspect received a percentage of 80%, so this aspect was declared "valid". This shows that the module contains clear learning outcomes and learning objectives, and the material presented is simple and in accordance with the scientific field. The Graphics aspect received a percentage of 91.3%, so this aspect was declared "very valid". This shows that the design in the developed module is good and engaging, and the images provided are clear and relevant to the material. Busljeta (2013) states that in making teaching materials, you must pay attention to things such as the composition of the display colour, as well as the type and size of the writing, in order to increase the motivation of students in the learning process. Based on the percentage of validation obtained from all aspects of the large group

test, it was found that the module was declared "very feasible" because it received a score above> 85%.

From the results of the user trial, researchers obtained several responses from students. Some students stated that the illustrations and pictures in the module helped them in understanding the material. However, they also suggested that the images in the module be enlarged to make it easier to observe, and some suggested adding photographs, illustrations, and diagrams to the module. In addition, some students complained that some parts of the module still used terms that were difficult to understand. Based on the feedback, the researcher increased the size and added pictures, illustrations, and diagrams on specific topics in the module to increase visibility and students' reading interest. We also replaced terms that were difficult to understand with additional explanations or synonyms that were more commonly used. In addition to the graphic aspect, the learning module was also evaluated from the linguistic aspect. Some students revealed that they had difficulty reading the text on the module due to the combination of background colour and text that lacked contrast, especially in the programming block code section. To overcome this, the researcher replaced the background colour with a more neutral colour and increased the contrast between the text and the background. This was done to ensure that all students could read the text clearly, including those with specific vision problems.

Overall, the percentage results of the validity test and trial were obtained as follows: validity test by media experts of 87.5%, validity test by material experts of 96%, small group trial of 87.8%, and large group trial of 85.7%. So, the average score of the percentage of product validity is 89%. Based on these results, the developed module was declared successful and very suitable for learning.

CONCLUSION

Based on the feasibility test conducted by media experts, material experts, and students as users, the embedded system learning module developed in this study is very feasible to use as teaching material for students to learn independently and creatively. By using the embedded system learning module, it is expected that SMK PGRI 3 Malang students can understand the conceptual and practical material needed for SMK graduates to be ready to enter the industry. This module adopts the syntax of the Project-based Learning model, which is equipped with material, practice questions, evaluation and assessment sheets, and Learner Worksheets to facilitate students in integrating theory with practice. In addition, the learning module is one of the solutions to overcome the limitations of teaching materials in organizing learning activities at SMK PGRI 3 Malang. This study has several limitations, such as the limited number of respondents, the limited material presented, and only the feasibility test. The findings of this study indicate that further research needs to be done to evaluate the effectiveness of using this learning module, add material to the module, and increase the number of respondents.

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