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Development of Project-Based Electronics Practicum Module with Virtual Lab to Increase Students' Creativity

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Abstract: One alternative source of learning physics can be a project-based practicum module with a virtual laboratory, especially for increasing student creativity. The purpose of this research is to develop a valid, practical, and effective project-based electronics practicum module with a virtual lab. The validity of the module is obtained from the validation results by three validators, namely content experts, learning experts, and media experts. The practicality of the module is obtained by giving response questionnaires to one lecturer in an electronics course and 12 students in semester 5A of the Physics Education study program. The effectiveness of the module is obtained by giving a project that can increase students' creativity. The developed module is very valid with an average validity of 3.70. The developed module is very practical with average practicality of 3.76. The effectiveness of the module is in the moderate category with a normalized average gain score of 0.51. The results show that the developed module is very valid, very practical, and effective so that it can be used as one of the teaching materials in electronics lectures.

Keywords: Creativity; Electronics; Practicum; Project-based learning; Virtual lab

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Introduction

Online learning is learning that is done without face-to-face, but through an available platform. All forms of subject matter are distributed online, communication is also carried out online, and tests are also carried out online. This online learning system is assisted by several applications, such as Google Classroom, Google Meet, Edmodo and Zoom. It seems that a transformation of physics learning is needed, from learning only in formal classes to virtual classes. The learning process must also emphasize the process of internalizing concepts more meaningfully, not just memorizing concepts. The task of all physics education experts is to develop a physics education curriculum, provide appropriate learning resources, and select interesting learning models so that learning objectives to generate higher-order thinking skills can be achieved well even though learning is done online.

One of the high order thinking skills is creative thinking which is able to develop creativity (Hermansyah et al., 2015). The ability to think critically and creatively is very important concern (Ritter et al., 2020) and is very much needed by the people in competing in the job market in the 21st century (Nugroho et al., 2019; Zulirfan et al., 2021). Creativity refers to the ability of students to find and use new ideas that may be unconventional or even strange, but are actually still rational in the context of learning. Creativity as a quality inherited by gifted individuals is assumed to be something given by nature, some people have it, while others do not, and the result of all forms of education (Munandar, 2012). In fact, creativity is not genetic, but acquired through habit. In other words, creativity is a skill that can be trained, so it has become

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the task of formal education as an important factor in being creative to produce creative human resources.

One of the efforts to overcome the lack of creativity of students is to provide learning resources that are able to accommodate students to generate creative ideas during the process of internalizing a physics concept through scientific discoveries and integrating the use of learning technology. One alternative learning resource can be a project-based module which during the learning process will be combined by applying a project-based learning (PjBL) model with a virtual laboratory. Virtual laboratory as a learning media that can give more experiences for students in learning. Learning media is a physical tool that is used and utilized to convey the content of learning material (Alika & Radia, 2021). Practicum instruction module based on PjBl can increase students' scientific process skill (Marjanah et al., 2021). In learning physics, an explanation at the visualization level is needed in order to increase students' mastery of concepts which can be done through the help of a virtual laboratory. This learning model is an innovative learning model that is integrated with learning technology to increase student creativity.

The PjBL is considered as situated learning which is based on constructivist theory (Nainggolan et al., 2020). PjBL requires students to design and develop systems that can be used to investigate and solve real-world problems (Sababha et al., 2016). The existence of PjBl model is expected to increase student learning motivation, increase the ability and creativity of students to create projects (Susanti et al., 2020). In PjBL, the students explore, make judgments, interpret, and synthesize information in meaningful and creative ways (Rubrica, 2019). PjBL models with virtual laboratories will provide flexibility for students to design practicums to carry out practical independently or in groups so that learning resources are needed to guide and at the same time encourage students to produce creative ideas. The learning resources in question can be in the form of interesting learning modules. This is in accordance with the results of the initial study in the electronics practicum class in the previous semester that students want a learning module that is more helpful during the online learning process so that students are able to design and conduct virtual experiments well and of course it is not much different from doing practicum directly at home as a real laboratory. This is certainly expected to build student creativity to design and make new discoveries.

The creative process always produces something new, original, and meaningful. The purpose of the creativity assessment is generally to measure creativity in solving a problem, both orally and in writing. Virtual laboratory can help the learning process in online mode (Hidayati & Masril, 2019). Significant increase in creativity can also be done by implementing virtual laboratories (Gunawan et al., 2017; Hermansyah et al., 2015) and also combined with cooperative learning (Gunawan et al., 2018). In addition, the application of a project-based learning model assisted by virtual media has succeeded in increasing the creativity of students in learning physics (Gunawan et al., 2017). Virtual laboratory-based learning modules have a significant impact on improving students' science process skills (Prabowo et al., 2017). Using a virtual laboratory is an investigation-based activity that encourages curiosity and investigation with certain techniques to find your own answers to problems (Yuliana et al., 2021). The application of learning modules combined with virtual laboratory media can help students understand concepts through studying the material on the module and understand the basic principles of experiments or observations in actual conditions through virtual laboratory applications.

Based on the findings of these studies, an effort was made to develop a project-based electronics practicum module with a virtual laboratory in the electronics practicum course. The development of a project-based electronics practicum module with a virtual laboratory is oriented towards increasing student creativity, which is developed in this study will provide a valuable contribution in supporting the development and improvement of the quality of physics learning at the university level during this pandemic which is synonymous with online learning. The research product in the form of a practicum module will be able to overcome the problem of the absence of adaptive and effective learning tools for increasing student creativity. On the other hand, the development of this learning tool will be able to increase the creativity of students, because learning is more student-centered and the concepts are discovered by students themselves so that learning will be more meaningful. Considering the need for teaching materials in the form of these modules, development research was conducted that aims to develop a project-based electronics practicum module assisted by a virtual lab that is valid, practical, and effective in assisting the learning process to increase student creativity.

Method

Types of Research

This research is research and development for 1 year by taking the ADDIE model, namely Analysis, Design, Development, Implementation, and Evaluation (Nadiyah & Faaizah, 2015) as shown in Table 1.

Table 1. Module Development Stages

Stages	Activity
Analysis	Analyzing the syllabus of the electronics practicum course, namely basic competencies and learning indicators as well as the characteristics of students
Design	Creating a project-based electronics practicum module format with a virtual lab
Development	Prepare the module according to the design that has been designed Conduct a validity test by asking content experts, learning experts, and media experts Revise the module according to the results of the assessment
Implementation	Conducting a limited test on semester V students of the 2021/2022 academic year in the Physics Education study program
Evaluation	Conduct an analysis of the practicality of the module in accordance with the data that has been obtained and revise it according to the suggestions

Data Retrieval Instruments

The data were collected by using validation, questionnaire, and worksheet. The worksheet is a electronics practicum project that available in the developed module.

Data Analysis Technique

The data obtained in this study consisted of qualitative data and quantitative data. Qualitative data were analyzed descriptively and interpretively through the synthesis of the results obtained. Module validation is based on the results of validators consisting of content experts, media experts, and learning experts. The results of the validation test will be compared with the validity criteria that have been determined as shown in Table 2. The content validation sheet contains 12 indicators, learning validation contains 5 indicators, and media validation contains 5 indicators with a score range of 1 to 4. The developed module is said to be good if it has minimum validity in the valid category.

Table 2. Validity Criteria

Validity score (*V*)	Category
$3.50 < V \leq 4.00$	Very valid
$2.50 < V \leq 3.50$	Valid
$1.50 < V \leq 2.50$	Less valid
$1.00 < V \leq 1.50$	Invalid

The level of practicality of the module was analyzed based on the results of the student response questionnaire which was compared with the practicality criteria as shown in Table 3. The module developed is said to be good if it has minimal practicality in the practical category.

Table 3. Practicality Criteria

Practicality score (*P*)	category
$3.50 < p \leq 4.00$	Very practical
$2.50 < P \leq 3.50$	Practical
$1.50 < P \leq 2.50$	Less practical
$1.00 < P \leq 1.50$	Impractical

The effectiveness of the application of the module on increasing student creativity is determined by comparing the value of the total normalized score gain (N-gain) against the N-gain criteria as shown in Table 4. How to calculate N-gain is shown in Equation 1. N-gain is a suitable method for calculating pretest and posttest scores (Hake, 1999). The developed module is said to be effective if the minimum effectiveness is in the moderate category as showed in Equation 1.

$$\langle g \rangle = \frac{X_{post} - X_{pre}}{X_{max} - X_{pre}} \quad (1)$$

as:
$\langle g \rangle$ = N-gain
Xpre = pretest score
Xpost = posttest score
Xmax = maximum score (100)

Table 4. N-gain Interpretation

N-gain $\langle g \rangle$	Category
$0.70 \leq \langle g \rangle \leq 1.00$	High
$0.30 \leq \langle g \rangle < 0.70$	Moderate
$0.00 \leq \langle g \rangle < 0.30$	Low

The qualification of each dimension of creativity is shown in Table 5.

Table 5. The Creativity Criteria

Mean	Criteria
$0.00 \leq \bar{X} \leq 40.00$	Very low
$41.00 \leq \bar{X} \leq 55.00$	Low
$56.00 \leq \bar{X} \leq 70.00$	Moderate
$71.00 \leq \bar{X} \leq 85.00$	High
$86.00 \leq \bar{X} \leq 100.0$	Very high

Result and Discussion

The result of this research is a valid and practical project-based electronics practicum module with virtual lab. The project-based electronics practicum module assisted by a virtual lab consists of 50 content pages which are divided into five sub-chapters of material, namely virtual lab applications, basic logic gates, Boolean algebraic laws, minimization of combination logic circuits, and the final project. This module has also been equipped with the assignment assessment guidelines given. The cover display and the contents of the module are presented in Figure 1.

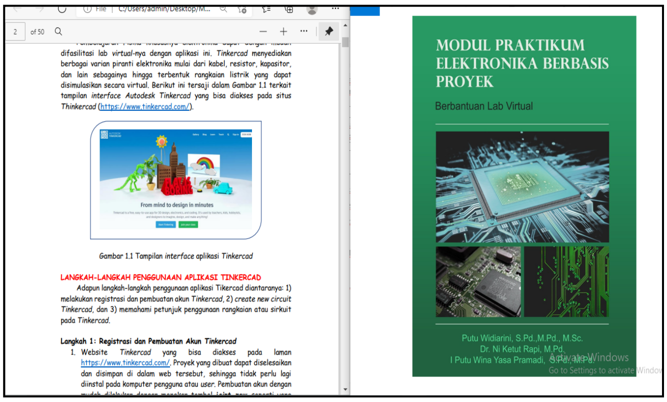

Figure 1. The Display of the Developed Electronics Practicum Module

Based on the module development stages presented in Figure 1, the practicum module that was tested for validity was a draft module that had been discussed with the writing team and received input from the course instructor. The learning device validation test was carried out by asking for the help of 3 physics lecturers as validators, namely content experts, learning experts, and media experts. The process is carried out by sending a draft module and assessment instrument via WA which is then assessed according to the validation sheet instrument that has been prepared. The total average validation of the electronics practicum module is 3.7 with a very valid category. The result of validation by content expert is 3.4 with valid category, validation results by learning expert is 3.8 with very valid category, and validation results by media expert is 4.0 with very valid category.

The practicality of the electronics practicum module that has been compiled is measured based on two things, namely 1) the response of the lecturer to the use of the module, and 2) the student's response to the use of the module. The data was taken from one supporting lecturer and 12 students who took basic digital electronics courses in semester V of the academic year 2021/2022 of Physics Education study program. The results of student responses are shown in Table 6.

Table 6. The Result of Students' Response

Statement	Average score
I really enjoy learning to use this module	3.58
The contents of this module are interesting to read	3.58
The appearance of this module is very attractive	3.75
The presentation of the material in this book is neatly arranged so that it is easy for me to understand	3.83
Through this module, I quickly understand the material given	3.58
This module does not burden me in studying	3.50
This module can help me in interacting with lecturers and with other students	3.58
All projects to be done in this module are very clear	3.67
Through this module, I can complete a given project either individually or in a group	3.58
The presentation of the contents in this module is very easy to understand and practice	3.67
I got new insights about virtual lab applications that are useful in learning physics	3.92
This module can give me comfort in studying	3.75
This module can hone my creativity from the assigned project	3.83
The writing in this module is easy to read	3.83
The sentences used in this book are easy for me to understand	3.91
The pictures and tables in this book are easy for me to understand	3.83
Total average	3.71

The average value of the total practicality of the module is 3.76 in the very practical category. These results were obtained from the practical value of the module by the lecturers of 3.80 in the very practical category and the practicality value of the module by the students of 3.71 in the very practical category.

Based on the results of a limited trial by taking a one case study design in class VA Physics Education study program for the academic year 2021/2022, a general description of the average value of student creativity before and after treatment is obtained as shown in Table 7. The average value of student creativity per dimension is shown in Table 8.

Table 7. General description of student's creativity

Statistics	Before	After
Mean	76.20	88.30
Standard Deviation	1.87	2.41
Qualification	High	Very high

Based on the data in Table 7, it was found that the average creativity of students after treatment was higher than before treatment. The treatment is the provision of a project-based electronics practicum module with a virtual lab. The mean value of creativity before treatment was 76.20 with standard deviation was 1.87 in the high category. The mean value of student creativity after treatment was 88.30 with standard deviation of 2.41 with a very high category.

Table 8. The Average Creativity Value Per Dimension

Dimension of creativity	Before		After	
	Mean	Qualification	Mean	Qualification
Fluency	81.70	High	88.90	Very high
Flexibility	71.80	High	87.70	Very high
Originality	75.00	High	91.70	Very high
Elaboration	72.10	High	85.00	High

In general, the mean value of student creativity per dimension after treatment is higher than before treatment as shown in Table 8. In the dimension of fluency, the average value of creativity before treatment was 81.70 in the high category, while after treatment was 88.90 in the very high category. In the dimension of flexibility, the average value of creativity before treatment was 71.80 in the high category, while after treatment was 87.70 in the very high category. In the originality dimension, the average value of creativity before treatment was 75.00 in the high category, while after treatment was 91.70 in the very high category. In the elaboration dimension, the average value of creativity before treatment is 72.50 in the high category, while after treatment is 85.0 in the high category. Based on the results of the gain score calculation, the effectiveness of the module is in the moderate category with a normalized average gain score of 0.51. So, the developed module is effective to improve student's creativity. One example of students' project can be shown in Figure 2.

AND 3 input dengan NAND 2 input

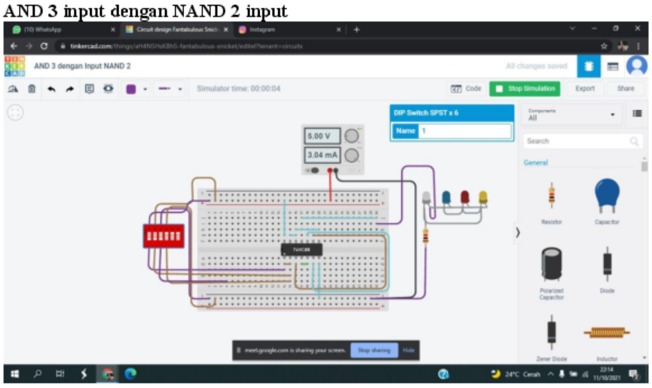

Figure 2. The Display of Student Project in Tinkercad Application

Based on the research objectives and research results, the discussion is focused on two main things, namely: 1) the validity of the developed module, 2) the practicality of the developed module, and 3) the effectiveness of the developed module.

Based on the results of the study, it was shown that the practicum module that was compiled was very valid and very practical to be applied in basic digital electronics courses. The validity of the module was assessed by three experts, namely content expert, learning expert and media expert. The modules assessed are the revised modules after being given input in a small discussion with the module compiler team. The content expert stated that the project-based electronics practicum module assisted by a virtual lab was valid, while the learning expert and media expert stated that the project-based electronics practicum module assisted by a virtual lab was very valid. The average validation score is 3.70 with a very valid category. So, the module can be used in lectures after repairs are made according to the validator's suggestion.

The practicality of the revised module through the input of the validators in the validation test activity, the learning tools developed were then tested on small group students. Small group trials were conducted on 37 students and observed by 1 lecturer. The practicality of using the module is known based on two things, namely: 1) the teacher's response to the use of the module and 2) the student's response to the use of the module. Data were collected using a response questionnaire. The average practicality value for the two types of data is the dose response of 3.80 in the very practical category and the student response of 3.71 in the very practical category. The average value of the overall practicality test of the module is 3.76 with a very practical category. In the process of implementing the use of modules in class for 5 weeks, it appears that students are increasingly accustomed to using modules and are helped in doing practical with virtual labs because in the module it has been explained in part 1 regarding the application of the Tinkercad virtual lab. This adds to the motivation of students to try using the Tinkercad application in trying to do electronics practicum.

This module was developed based on the independent campus learning curriculum which prioritizes case-based, problem-based, or project-based learning. In this module, assignments are developed in the form of projects that can train students' creativity in completing projects according to the work deadline that has been set. Through the application of PjBL, it has provided opportunities for students to complete project assignments according to their understanding of concepts and creativity. The tasks that are done become better and more varied. In addition, learning with the help of a virtual lab also makes it easier for students to practice doing practicum within the limitations of practical tools and materials. Students can try to do the practicum repeatedly until they understand the concept being tested. This is in line with the results of research by Susanti et al. (2020) which states that the development of PjBL based module can increase creativity. Beside that the application of a PjBL model with a virtual lab can increase student creativity (Gunawan et al., 2017; Widiarini et al., 2021). PjBL models can be used as an alternative to learning physics (Özer & Özkan, 2012; Santyasa et al., 2020; Thomas, 2000, Trianto, 2009; Utami et al., 2019). Learning that utilizes virtual labs can increase student creativity more optimally (Gunawan et al., 2018).

In addition, the development of learning materials such as modules using the ADDIE development model has been widely carried out. The steps for developing modules have been carried out systematically in this study so that practicum modules are very valid and very practical to use in learning activities. The results of this study are in line with research conducted by Nadiyah & Faaizah (2015) which states that one of the development research models that can be used in developing PjBL tools is the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Bhakti & Napis ,(2018) also developed a simulation-based learning tool using the ADDIE model. This development model is easy to implement and can produce learning tools that are valid, practical, and in accordance with user needs.

Conclusion

Based on the research results and discussion, the following conclusion can be drawn that the developed module is very valid with an average validity of 3.7, and the developed module is very practical with an average practicality of 3.76. This result shows that the module can be used as one of the learning materials in digital electronics lectures. The suggestions for improving this module are by conducting wider trials and for a longer period of time so that the effectiveness of using the module is more proven.

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