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Validation and Testing of STEM Project-Based Virtual Learning Modules to Improve Higher-Level Thinking Skills

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ABSTRACT
The purpose of this study was to develop a virtual learning module based on STEM projects to improve students' higher order thinking skills. This research is a Research and Development research by following the steps of the ADDIE model (Analysis, Design, Develop, Implementation and Evaluation). The Analysis Phase is an analysis of the initial study of the need for developing STEM-based Virtual Learning Media. This stage is carried out through survey research. The Design stage is the stage of designing Virtual STEM learning, designing technology forms, placing HOTS elements, STEM project design, manufacturing techniques, and calculating the size and aesthetics of the media. The Develop stage makes the media into a media that is declared valid according to the validator, where the validator consists of 2 material experts, 3 media experts, 2 pedagogical experts, and 2 teachers. Implementation phase is a module testing phase for students. The research instrument used was an expert validation sheet and a trial assessment sheet. Data analysis was carried out by tabulating the data from the assessment results from the validator. The module draft can be declared valid and practical if the average score of all items is equal to or more than 3.00. The results obtained are valid project-based STEM virtual learning modules with an average assessment score of more than 3.00. And the results of testing the module on students show that this module has been stated to be interesting, useful, and easy to use. The next stage is a project-based virtual STEM module that can be tested through experimental research.

INTRODUCTION

The industrial revolution 4.0 is very influential in the world of education as a new millennium era in the history of civilization, this is supported by increasingly developing information technology. Education in Indonesia has experienced a transition from face-to-face learning to online system learning since the outbreak of the disease 19. The teacher as an educator for students must review and study the chasing media that has been used so far. Learning media is a tool that must exist to complement formal education and provide interesting experiences for students [1] so that learning can be carried out properly, both face-to-face and online learning. However, the teaching system, building high-order thinking skills, scientific attitudes, and problem solving in the real world in science need to be trained [2] instead of being preoccupied with problem solving activities and the ability to remember. Unfortunately, the high-order thinking ability of Indonesian children is still low, as the results of the 2018 TIMSS study and several other studies, the thinking ability of our students is only at the low-order thinking skills stage [3]. Currently, most of our students experience boredom and boredom due to the ineffectiveness of online learning, so the negative impact is that students become stressed by tasks or homework that are not relevant to the nature of science itself [4].

Currently learning in Indonesia is carried out online, so an alternative experimental activity is carried out using a virtual laboratory. A virtual laboratory is one of the media used for physics learning activities on certain concepts, where there are limited tools for carrying out experiments [5] and helps visualize various abstract physics concepts [6]. Virtual laboratories are effective because students can actively do their experiments without the help of assistants or teachers [7]. Following the results of research conducted by Dewa, that the application of learning using a virtual laboratory can make students active in the learning process [8], this will provide opportunities for students to find information on their own. STEM education is a learning strategy that can be done to support the virtual laboratory activities, which are expected to improve students' higher-order thinking skills to face the challenges of the 21st century [9].

According to Bryan, integration of STEM elements as defined by the National Research Council, US: **i.** Science is the study of nature, including natural laws related to physics, chemistry and biology. Treatment or application of facts, principles, concepts, related to science, **ii**. Technology consists of all human and organizational systems, knowledge, processes and devices used to create and operate technological artifacts, **iii**. Engineering is knowledge of the design and creation of products and processes to solve problems, **iv.** Mathematic is the study of patterns and relationships between numbers, numbers and shapes [10]. Metacognitive theory and social interaction can be built by STEM integrated learning [11].

STEM learning that has been carried out at this time has encountered many obstacles, according to Margot [12], reporting that there are obstacles in implementing STEM such as pedagogical challenges, curriculum challenges, structural challenges, concerns about students, concerns about assessment, and lack of teacher support. One of the ways to minimize obstacles in implementing STEM is by providing a STEM virtual learning module. At present, many STEM projects have been carried out in direct learning, but due to certain conditions online learning is an integral part of learning from classroom learning. Then the presentation of a project-based virtual STEM project will be an option for implementing STEM during a pandemic so that STEM learning can still be done.

The application of a virtual laboratory in experimental activities is assisted by a module that is useful as a guide for experimental activities to run well. Student worksheets are sheets that contain instructions for students to carry out real activities with the objects and problems being studied, so as to increase the competence of students' knowledge, attitudes and skills. The collection of several student worksheets will be organized into a module. This is in accordance with Daryanto's opinion in 2013 [13] ,that the module contains a set of learning experiences that are arranged systematically and completely, so that it can help students master learning independently. Virtual laboratory worksheets are considered to be very effective and efficient in the current online learning process [14].

The implementation of STEM in learning, especially science learning in Indonesia has not been encouraging, this shows that the implementation of STEM in Pekanbaru is still very low [15]. Therefore, the application of the STEM approach must be developed. It is necessary to change the paradigm of thinking, from STEM which is considered to be difficult to implement into a more flexible STEM so that it is easy to implement. Virtual lab application-based project learning is seen as an option in applying the STEM approach to science learning. Furthermore, Alneyadi emphasized that virtual lab applications are the best solutions that meet the needs of science education in situations of unavailability of laboratory resources. In addition, virtual labs are seen to be able to minimize the use of time in the science practice process [16]. Virtual lab technology provides several benefits for students as well as teachers. Virtual STEM is flexible and provides students with the variability of experimental projects that a greater number of students can undertake. Students can work independently. This method also provides easy configuration and resistance to damage [17].

STEM education is better teaching than separate STEM subjects and STEM must be taught using an integrative subject approach. Currently various countries provide professional development experience to show teachers how to incorporate STEM into their teaching practice [18].

Based on this description, to train students' high-level thinking skills in independent learning during the Covid-19 pandemic, it is necessary to develop a virtual laboratory-based physics learning module that will contain activities that train high-level thinking skills. The developed module consists of several student worksheets that are arranged chronologically which contains work procedures, observations, and questions related to experimental activities that can help students find concepts, and conclusions of the experiments carried out on the intended subject matter. So that virtual laboratory student worksheets are considered to be very effective and efficient in the current online learning process [14].

One of the applications used in virtual lab experiments is liveware. This application can be used for free both online and offline. Liveware is a learning medium that plays various circuit components, creates your own electrical circuits, and sees how they work in real time. This application can be enjoyed for anyone who likes to do scientific experiments. For teachers this application is used to demonstrate science experiments in class and for students to explore inside and outside the classroom. The purpose of this research is to develop a virtual module based on a STEM project on Dynamic Electricity material to increase high Order Thingking Skills (HOTS).

METHOD

Research on the development of a project-based STEM virtual learning module on dynamic electricity material will be carried out at the Physics Education Laboratory of the PMIPA Department, Riau University. This development research design uses the ADDIE (Analysis, Design, Develop, Implement, Evaluate) model according to Branch [19]. These stages are carried out as follows:

The Analysis stage is carried out to look for learning problems and filter teacher and student opinions about learning patterns that are following the curriculum and do not burden students during this pandemic. And planning solutions that are useful for determining appropriate learning patterns for students and teachers, so that learning can run as it should. This study has been carried out and found that there are time constraints in carrying out manual STEM projects, especially Dynamic Electricity material [20].

The design stage is carried out by researchers to design the media needed by students and will be a solution to the needs analysis that has been carried out. At this stage a cover format will be compiled, the contents of the learning module are following the needs of students. on online learning which consists of various components including a guide to the use of liveware applications, HOTS-based Virtual Experiments, and STEM-based virtual projects.

The Development stage is the stage of developing the Virtual STEM Project module and evaluating the module validation by material experts, media experts, pedagogies, and users (teachers).

Implementation stage, is the small-scale module trial stage conducted on 10 middle school students, to see whether the modules created can be used by students properly and also to filter student opinions about the virtual STEM Project module. The data collection instrument used in this study was an instrument in the form of expert validation sheets and also a virtual module test instrument. The validation instrument was developed according to the validation aspect as shown in Table 1.

Table 1. Type of Validation, Aspects and number of items for expert judgment on Dynamic STEM Virtual Electricity Project

No	Validation Type	Validation Aspecs	Number of Question Items
1	Media Validation	Design Quality	3
		Visual Appeal	3
		Interactive	3
		Felxibility	3
		Liveware Function	3
2	Material Validation	The Truth aspect of the concept	4
		Aspects of the depth and breadth of the material	3
		Aspect of presenting the concept	3
3	Pedagogic Validation	Inherence to the curriculum	4
		STEM integration	3
		HOTS aspect	3
		Liveware function	3
4	User Validation (Teacher)	Coherence with curriculum	7
		The link between STEM and learning	7
		Virtual lab components	4
		Aspects of learning media	3

Aspects and questions for the virtual module test instrument can be seen in Table 2.

Table 2. Aspects and number of items of Virtual STEM module testing instruments

No	Aspecs	Guestion Items
1	Interest	Cover display and module contents. Virtual STEM is interesting
		The project in the Virtual STEM Module is of interest to me
		The use of the Lifewire application in Modules is interesting
2	Usefulness	Through this module I was trained to work on projects
		Designing an electrical circuit as you wish
		The STEM project has benefited me
		The Virtual STEM module challenges me to be able to design more complex projects
3	Ease of Module	I can understand the goal of a virtual STEM project
		The activity steps in the module are easy to understand
		The Activity steps in the Module are easy to do
4	Ease of Application	Tutorial using Lifewire helps me in learning to use Lifewire
		Livewire application is easy for me to understand in no time
		The Livewire application was easy for me to understand in no time
		Electrical circuits can be made faster
5	Interaction	Virtual STEM projects I can do myself at home
		Virtual STEM projects can also be done in groups with friends

The data analysis technique was carried out by tabulating the data from the assessment results from the validator. Validation is complete, if all validators have assessed a minimum of 3.0 for each question item given. The index of validity and practicality of the draft module can be declared valid and practical, if the average score of all items is stated as in Table 3.

Table 3. Criteria for the Validity and Practicality of the Module

No	Aspecs	Validation Indexs Validitas	Criteria
1	Validity Index	≥ 3,00	Valid
2	Practicality Index	≥ 3,00	Practical

RESULTS AND DISCUSSIONS

Research on the development of the STEM Project virtual module was carried out by referring to the following stages:

Analysis Stage

Through this analysis of needs, STEM learning is formulated which is carried out virtually using the lifeware application on Dynamic Electricity material. In general, STEM has not been implemented optimally in schools. Most of science teaching is still oriented towards content achievement through knowledge transfer, and lack of training in thinking skills and limited time are the main obstacles in implementing STEM projects in schools. Virtual laboratories can overcome obstacles related to experiments [21]. Virtual Engineering Sciences Learning Lab can overcome the low level of female participation in STEM and show high student interest and improve student learning experiences [22].

Design Stage

This research will be developed, of course starting with a prototype design that will be developed. Even though the learning is virtual, the prototypes that will be used in the inventory first, for example, are lamps, voltage sources, switches, cables, Ampermeter and Voltmeter. All equipment that will be used in virtual learning is taken from the Livewire application.

The structure of the text plays an important role in ensuring the ease with which the reader understands the teaching material. The effectiveness of learning is also ensured by the existence of a clear text structure. To fulfill this purpose, the text structure of this virtual STEM module is built following the format shown in Figure 1.

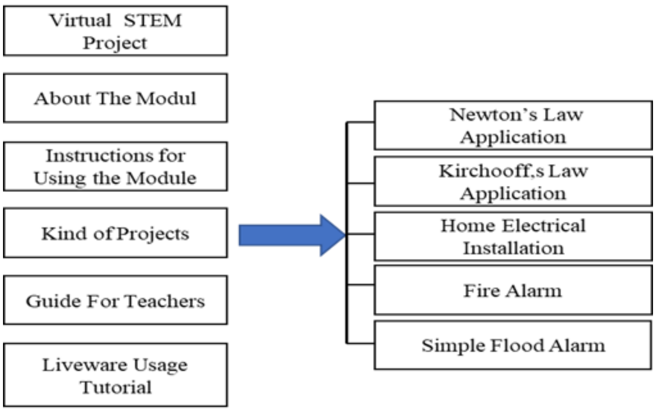

***Fig 1.** Text structure of the Virtual STEM module*

The project to be made is a virtual one, this project is carried out in a virtual world by students. The success of this project will be declared a success, if the lights installed by the students are bright. These projects can hone students' skills about circuit design and circuit shape. Even students can prove whether the circuit they made can function properly.

Development Stage
Virtual lab technology provides several benefits for students as well as teachers. This technology can minimize the cost and time of carrying out experiments in the laboratory. Virtual laboratories can be carried out by many people independently at the same time, are easy and have damage resistance [17]. Combining PjBL with STEM can increase effectiveness, generate meaning in learning and influence student attitudes in pursuing future careers [23].

The development of the STEM module begins with making: a draft module, placing HOTS elements in the module, virtual experiments and the types of projects to be implemented, can be seen in Figure 2, Figure 3 and Figure 4 below.

a. Cover the module and about the module

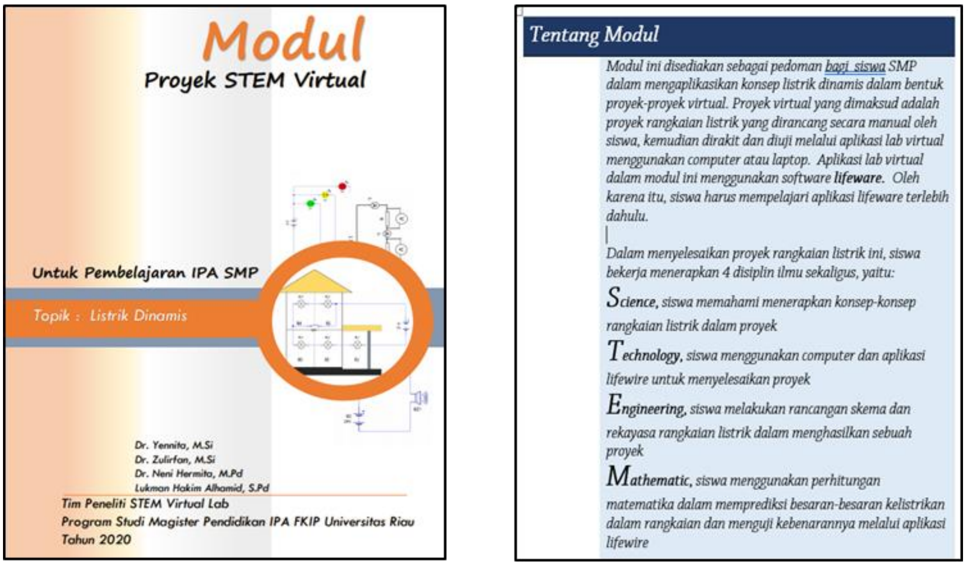

Fig 2. *Module Cover Design and About the Module*

Figure 2 shows the module cover design and the module design. The cover of the module is designed to contain images that display STEM activities. The cover display is made as attractive as possible with the use of images or graphics to attract students' attention and is also equipped with the overall module title, material, and the identity of the module author. In addition, the design of the module contains the purpose and use of the module, and there is also an explanation of the STEM that will be applied in the module.

b. Examples of Virtual Experiments and HOTS Element Placement
There were 5 virtual experiments by including HOTS elements, namely the Invention of Ohm's Law, Series Series, Parallel Circuits and Combined Circuits. An example of a HOTS-based Virtual STEM experiment is shown in Figure 3.

Figure 3 shows an example of a virtual experiment, namely on Ohm's Law Discovery material. The project content component in the module contains an introduction, activity objectives, tools and materials, then there is a task description section which is an explanation of work steps. This work step is made with the aim of directing students on how to carry out experimental activities in the project. Furthermore, in the activities of carrying out projects containing STEM components and cognitive processes. As shown in Figure 3, the stages of science engineering, science math, and technology are shown.

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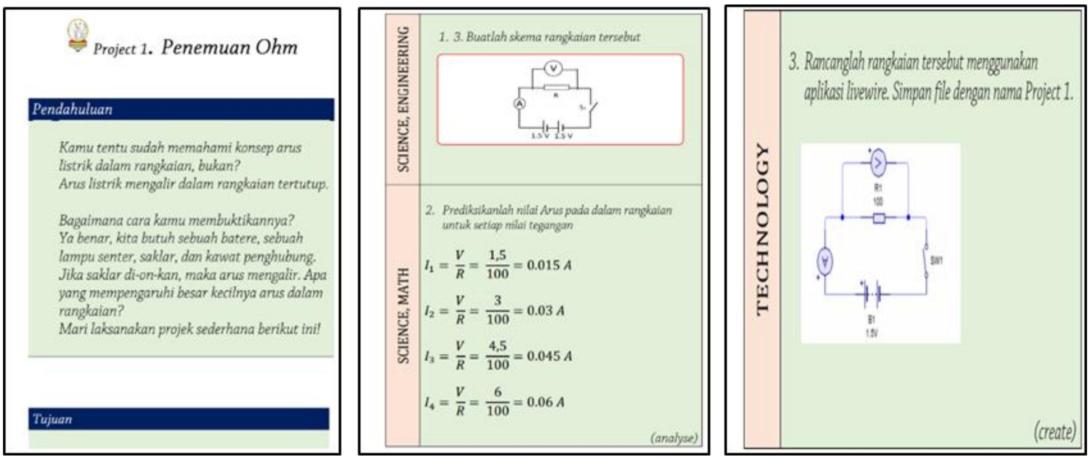

Fig 3. One example of virtual experiments and placement of HOTS elements

c. Example of a Virtual STEM Project

Independent project tasks are provided such as, Household installation, Fire alarm, Flood alarm. One form of the project can be seen in Figure 4.

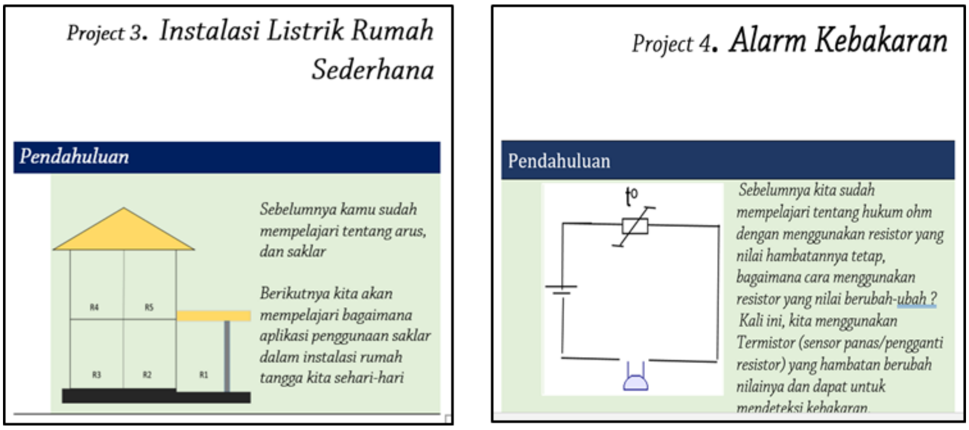

***Fig 4.** Example of a Virtual STEM Project*

Figure 4 shows an example of a virtual STEM project, namely project 3 Simple Home Electrical Installation and project 4 Fire Alarm. The virtual STEM project consists of an introduction that contains an introduction related to the experiment to be carried out, then the objectives, tools and materials, as well as activities to carry out the virtual STEM project which contains STEM components.

Module Validation

After the module is developed, an expert assessment of the virtual STEM module is carried out as seen from the overall assessment items by material experts, media experts and pedagogists on the STEM virtual module. Each type of validation was assessed by 2 or 3 validators. The results of the validation are presented as follows:

Material and media validation

Material validation was carried out by two material expert lecturers and media experts from PMIPA FKIP Riau University lecturers, the questionnaire used was 10 questions for material experts and 15 questions for media experts, with a range of questions 1 - 4.

Indicators of expert assessment of the material aspects contained in the STEM virtual module include aspects of concept correctness, aspects of depth and breadth of concepts and aspects of presentation.

While the media expert's assessment indicators on the media display aspects contained in the STEM virtual module include 5 aspects, namely design quality, visual appeal, interactive, flexible, and liveware functions. The assessment scores that have been obtained through a questionnaire can be seen in Figure 5 and Figure 6.

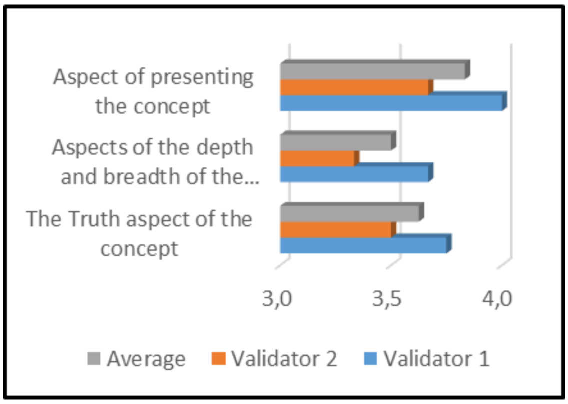

Fig 5. *Expert assessment of the material aspects contained in the virtual STEM module*

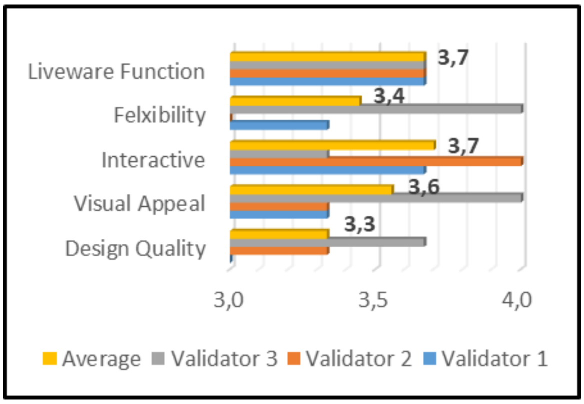

Fig 6. *Media expert's assessment of the media display aspects contained in the STEM virtual module*

Pedagogic Validation and User Expert (teacher)

Indicators of expert assessment of the pedagogic aspects contained in the module include coherence with the curriculum, STEM integration, aspects of improving HOTS, and livewire functions. And indicators of expert assessment of user aspects contained in the module include coherence with the curriculum, STEM linkages with learning, virtual lab components, and aspects of learning media. Pedagogic validation and expert users can be seen in Figure 7 and Figure 8.

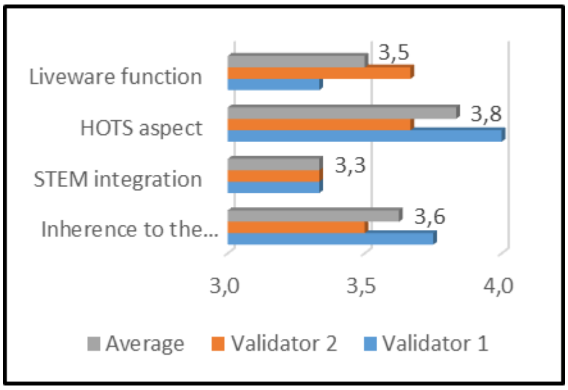

Fig 7. *Expert assessment of Pedagogic aspects contained in the virtual STEM module*

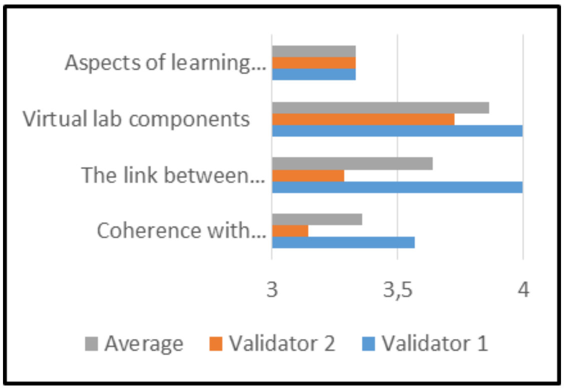

Fig 8. *Expert assessment of User aspects contained in the virtual STEM module*

From the validation results, it can be seen that the overall validation has exceeded a score of 3.0, this means that the module made is valid and can be tested on students.

After completing the validation, there are product changes before and after validation. Among them are:
1. Prior to validation, there were difficulties in placing lights on the puzzle house's ceiling, so repairs were made to make it good and the lights could be placed on the puzzle house's ceiling.
2. Before validation, there were difficulties in assembling the puzzle, so improvements were made by making the puzzle numbered on each piece, to make it easier to assemble.
3. Prior to the initial validation, the color of the puzzle pieces was clear (not like a greenhouse), so improvements were made by giving the roof of the puzzle house a color, so that it really looked like a mini house (like a greenhouse).

Implementation Stage
The indicators for student assessment of the STEM virtual module consist of aspects of interest, benefits, ease of module, ease of application, and interaction. Student assessment of the module through virtual experimental trials and the creation of virtual STEM projects received positive responses from students and were very enthusiastic about making their own series according to their wishes. Through project work students will get additional knowledge and skills [24]. The results of the trials that have been carried out on 10 students have obtained the results as shown in Figure 9.

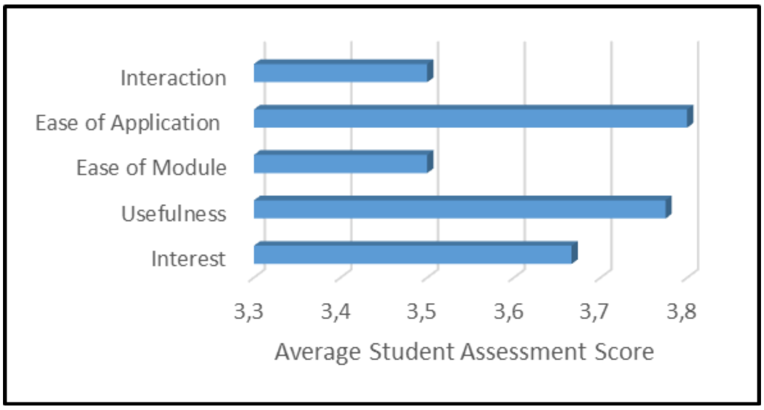

Fig 9. *Student Assessment of the STEM virtual module*

After the test data were analyzed, it was found that this module was practical and had ease of operation, both ease of use of modules and ease of use of lifeware applications. Based on these criteria, it shows that the module can be understood by students well, the design of the module is attractive and the module is systematic, and interactive so that students can easily understand the contents of the module.

A school without access to science laboratories or equipment can use virtual simulations to offer students experiences that are not currently available due to limited resources. In addition, simulations are a safe place for students to study and practice effectively before they carry out research in the field. Virtual lab technology can improve the quality of science learning for schools that are poorly equipped. Students can collect data for their own use through their mobile devices. and can align their findings by collaborating with researchers anywhere in the world [25].

In direct experiments, students are often preoccupied with handling equipment settings and taking measurements, the effectiveness of laboratory activities is the only way to improve scientific understanding. Virtual Lab can be an effective solution to this problem [26]. The difference between a virtual laboratory and an ordinary laboratory is that when conducting direct experiments there are obstacles in terms of preparing tools and materials, as well as costs, and it takes quite a long time so that the experimental process carried out by students is less effective. The virtual laboratory makes the concept of learning science easier and more effective in training students' thinking skills. According to Aşiksoy & Islek [22], The use of virtual laboratories in science education has increased student achievement and satisfaction in conducting experiments.

Virtual labs make science concepts easier and faster to apply and positively influence student attitudes. Besides that, Trúchly, states that virtual and augmented reality applications, multimedia applications, virtual labs, and real laboratories are new trends that can help students get involved in the STEM field, and help them to imagine and understand difficult and abstract problems [17]. Implies that project-based STEM in schools is more beneficial for students to reduce the achievement gap between students [27].

The research conducted by the author uses a liveware application because this application is an electronic simulation program (computer laboratory). This application is very suitable for use in electrical installations because it is used to simulate electronic circuits. There are many electronic components that can be used in this liveware application. So it is very suitable for use on Dynamic Electrical materials taken in the virtual module of the STEM project that has been created.

Based on the research that has been done by the author, the resulting product in the form of a virtual learning module based on STEM projects is valid and practical to use. This module is valid because the overall validation results based on the assessment of material experts, media expert assessments, pedagogic assessments, and user expert assessments (teachers) have exceeded a score of 3.0. A series of these processes can be stated that the module is feasible to be used in science learning. Furthermore, this module has been practical to use because based on the results of trials in limited use that have been carried out, the overall score has exceeded 3.0. According to Alneyadi [16], dramatic changes and advances in digital technology have begun to change the nature of practical work and replace it with virtual laboratory applications. In fact, the importance of practical work is clearly seen in the several research studies that have been carried out. This module has ease of operation, both ease of use of the module and ease of use of lifeware applications, as well as getting a positive response from students. The advantage of this module is that the design of the STEM virtual project module can train students' higher-order thinking skills. In this module there is a STEM process with steps, namely Science, Technology, Engineering, and Mathematics.

CONCLUSION AND SUGGESTION

This development study has produced a project-based Virtual STEM module, in which the module has been declared valid by material experts, media experts, pedagogists, and user experts. And after being tested on students, they get a positive response, and students state that the modules and applications used have ease and practicality in their use. It is hoped that this module can be used by students as an alternative that is able to make students learn independently, offline and online, and can improve students' higher-order thinking skills.

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