Islamic Journal of Integrated Science Education (IJISE), Vol. 1 No. 1, March 2023, pp. 1-15
DOI: https://doi.org/10.30762/ijise.v2i1.885

Islamic Journal of Integrated Science Education (IJISE)

Program Studi Tadris IPA
Institut Agama Islam Negeri Kediri
e-ISSN : 2986-0865
https://jurnalfaktarbiyah.iainkediri.ac.id/index.php/ijise

Development of Virtual Laboratory Electronic Student Worksheet Using PjBL to Improve Critical Thinking Ability

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Abstract: The use of virtual laboratories is a solution for schools that have not been able to carry out practical activities directly. This study aims to develop virtual laboratory electronic student using PjBL which can improve students' critical thinking ability. The research method used is the research and development (R & D) method with the ADDIE development model (analysis, design, development, implementation, & evaluate). The research subjects used were 30 students of class XII IPA who were selected using a purposive sampling technique. Data collection instruments consist of expert validation sheets, student response questionnaires, and critical thinking ability tests (pretest and posttest). The data analysis techniques used are Likert scale and n-gain analysis. The evaluation of the feasibility of electronic student worksheet by the expert got an average percentage of 85.41% with a very valid category, student test results got a n-gain value of 0.38 with a moderate improvement category, and the results of student responses got an average percentage value of 91.35% in the very good category. Thus, the developed virtual laboratory electronic student worksheet using PjBL can Improve students' critical thinking ability.

Keywords: Critical Thinking Ability, Electronic Student Worksheet, PjBL

Article History:
Received: 13 January 2023; Revised: 13 March 2023; Accepted: 20 March 2023; Published: 30 March 2023

Citation (APA Style):
Julianti, B., Haryadi, R., & Oktarisa, Y. Development of Virtual Laboratory Electronic Student Worksheet Using PjBL to Improve Critical Thinking Ability. *Islamic Journal of Integrated Science Education (IJISE), 2*(1), 1–15. https://doi.org/10.30762/ijise.v2i1.885

INTRODUCTION

At this time, the development of science and technology in the world of education is growing quite rapidly and facilitates learning activities. The technology used in the learning process is very useful in helping teaching and learning activities, one of which is the visualization of the material. The rapid development of information and communication technology has encouraged various educational institutions to utilize electronic learning systems (e-learning) to increase the effectiveness and flexibility of learning (Sar & Misra, 2020).

In learning activities at school, physics is one of the subjects that is considered quite difficult and less attractive to students. Supardi U.S. et al. (2015) explained in his research that physics subjects were considered quite difficult by students, this was because physics learning took place conventionally such as memorizing formulas and working on problems in a monotonous way. In another study, Hamid (2011) stated that students at school were still passive in learning physics, students were less active in scientific work, had a scientific attitude, and could not find their own scientific results planned by a teacher. According to Astalini et al. (2018), students who feel happy learning physics will increase their time to explore physics, find out problem solving in physics and increase knowledge about physics. But in reality, not many students like physics because they think that physics is difficult, one of which is Faraday's law (electromagnetic induction). The difficulty of students in learning this material is influenced by the difficulty of students in describing or illustrating a concept, especially the absence of practical activities (Prescott et al., 2002).

Active learning through practicum activities can make new knowledge gained by students to be associated with everyday life (Laili & Lufri, 2019). However, not all schools have adequate facilities to carry out practical activities, one of which is senior high school 1 Bayah, Lebak, Banten. Based on the information obtained from the physics subject teacher, it is very difficult to carry out practicum in the laboratory because there is no special technician in the physics laboratory who can guide practicum activities. Therefore, the use of technology can be a solution for the implementation of practical activities in the form of a virtual laboratory (Hidah & Sudibyo, 2022). In physics learning, a virtual laboratory is one of the technological developments in the field of education, a virtual laboratory is a place or system that students can use in carrying out online. Jaya (2013) suggests that the use of virtual laboratories can make learning more effective because students are able to carry out

practicums through internet access or without internet access, so that students no longer have difficulty carrying out practicals due to lack of facilities. In addition, the use of electronic student worksheets is also one of the uses of technology in education that can make it easier for students to access learning tools (Hidayah et al., 2020). The use of electronic student worksheets made in an application can make it easier for students when carrying out learning activities, electronic student worksheets can also be equipped with interesting features to further increase student interest during learning activities (Subekti & Prahmana, 2021).

PjBL is a legitimate project-based learning, PjBL is designed to be used in solving complex problems and is needed by students in conducting investigations in learning (Daniel, 2016). The main goal of PjBL is to make students have the skills to solve problems, improve motivation to learn, communication skills, skilss to collect data, and skills to think critically.

Critical thinking ability is a high-level thinking ability that must be possessed by students in the 21st century (Binkley et al., 2012). Critical thinking is part of an effort to collect, interpret, analyze, and evaluate with a view to drawing conclusions that can be proven valid (Fristadi & Bharata, 2015). Critical thinking ability are the ability of each individual in using their thinking processes to analyze an opinion or argument and can provide interpretations based on rational and logical perceptions so that they can be understood by others (Ennis, 1985).

In this study, the authors developed electronic student worksheets based on virtual laboratories using PjBL to improve students' critical thinking ability. In implementing electronic student worksheets based on virtual laboratories using PjBL, students are given the task of solving complex problems and solving them through investigations in virtual laboratories. Therefore, the application of electronic student worksheets based on virtual laboratories using PjBL can stimulate students' critical thinking ability because students can carry out activities to analyze the results of investigations and interpret them in solving problems(Astra et al., 2019).

Therefore, the aim of this research is to produce an "virtual laboratory electronic student worksheet using PjBL to improve critical thinking ability ", with the development of this electronic student worksheets, researchers hope that electronic student worksheets can make students interested in learning physics and can improve students' critical thinking ability.

DOI: https://doi.org/10.30762/ijise.v2i1.885

METHOD

This research is a type of research and development (R&D) with the ADDIE development model. The ADDIE development model consists of 5 stages including analysis ,design, development, implementation and evaluation (Maribe, 2009). In this study, the product produced by the researcher is a virtual laboratory electronic student worksheets using PjBL on Faraday's law material to improve students' critical thinking ability. The research flow is presented in the following **Figure 1**.

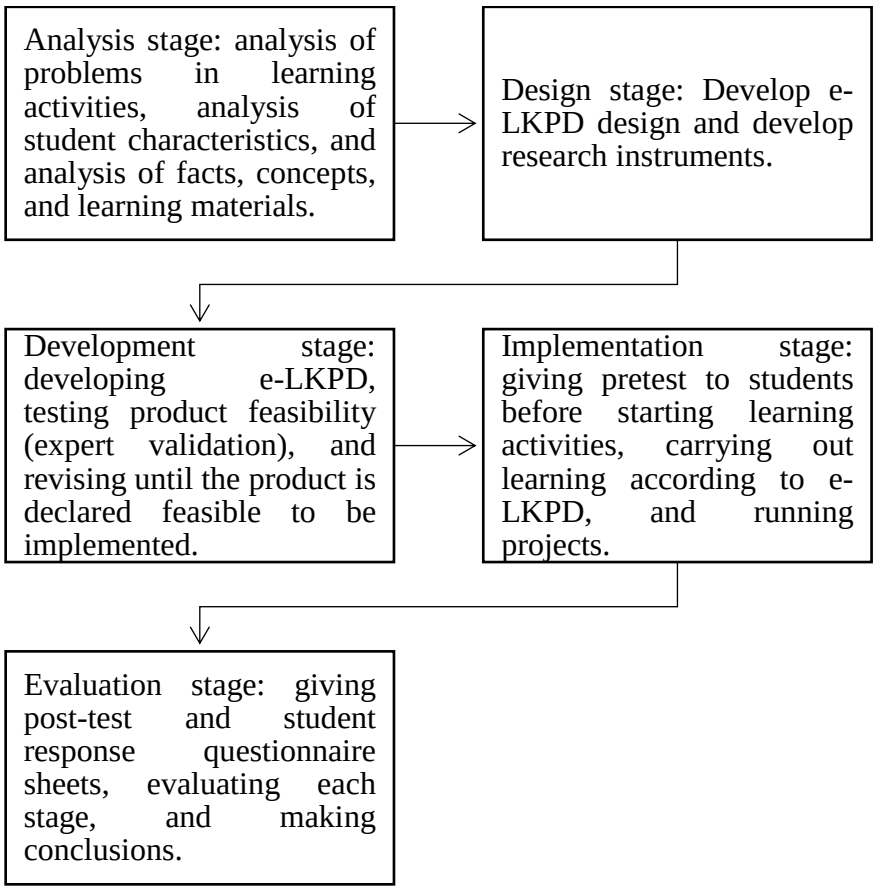

Figure 1. Research flow

Subjects or respondents in this study were students of class XII IPA at Senior High School 1 Bayah with a total of 30 students who were called test subjects. Subjects or respondents were selected using the purposive sampling method, namely the selected or determined sample. Determination of the subject or respondent is done based on the recommendation of the physics subject teacher at Senior High School 1 Bayah with moderate ability.

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Prior to testing, the product feasibility test is carried out first. Researchers compiled research instruments consisting of 2 types, namely tests and non-tests. The research instruments included questions of thinking ability for the type of test as well as expert validation sheets and student response questionnaires for non-test types. Critical thinking ability are compiled based on indicators of critical thinking ability, these indicators include (Ennis, 1985): (1) providing a simple explanation; (2) conclude; (3) provide further explanation; and (4) develop strategies and tactics. The expert validation sheet consists of 2 fields, namely the material/content field and the media field, while the student response questionnaire sheet is prepared based on indicators consisting of material content, language, and student interest in the use of electronic student worksheets. Data collection consisted of a questionnaire containing expert validation data (material/content and media) and the results of student responses to the use of electronic student worksheets, as well as critical thinking ability test questions (pretest and posttest) which were given before and after the implementation of learning as in the research design in the **Table 1**.

Table 1. Research design pretest-posttest only control group design

Pretest	**Treatment**	**Posttest**
O_1	X	O_2

Description:

O_1 : critical thinking ability pretest

X : treatment with virtual laboratory electronic student workhsheet

O_2 : critical thinking ability posttest

Data analysis in this study was carried out quantitatively, including by analyzing the results of expert validation sheets, student response questionnaires using a likert scale, and analyzing student learning outcomes through analysis N-gain as in **Equation 1** (Hake, 1998). The electronic student worksheets product is declared feasible if the results of the expert validity test are declared feasible and the learning outcomes and student response results obtain the expected value.

$$N - gain = \frac{posttest\ score - pretest\ score}{100 - pretest\ score} \quad \text{.....(1)}$$

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The average N-gain value obtained is described through the improvement criteria shown in **Table 2** (Hake, 1998).

Table 2. N-gain average criterion

Average *N-gain* (<g>)	**Interpretation**
<g>> 0,70	Tall
0,30 ≤<g>≤0,70	Currently
<g>< 0,30	Low

FINDING AND DISCUSSION

Finding

Results of the research and development of virtual laboratory electronic student worksheets using PjBL starting from the analysis stage to the evaluation stage are described as follows. In the first stage, an analysis of the basic problems in physics learning activities at Senior High School 1 Bayah was carried out, namely that there had never been practicum activities in physics subjects caused by the lack of facilities and there were no special technicians to guide how to use existing tools. Ostroukh & Nikolaev (2013) explained that practicum with a virtual laboratory has a significant impact on the student learning process in the classroom and leads to quality learning. Therefore, researchers developed a virtual laboratory electronic student worksheets using PjBL as teaching materials to support virtual practicum activities.

At the design stage, a product design is carried out in the form of an electronic student worksheets design. The electronic student worksheets is designed with a contemporary concept and bright colors so that it can attract students' interest when using the electronic student worksheets. Electronic student worksheets is designed online on the google site and liveworksheet so that it can only be accessed using an internet connection. In addition, at this stage, research instruments were arranged in the form of expert validation sheets, student response questionnaires, and questions about critical thinking ability.

At the development stage, product development and product feasibility tests are carried out. Overall, the product validation results were declared feasible to be tested with the results of 85.41% for material experts and 90.38% for media experts. Opinions, suggestions, and

input from validators become evaluations for further improvement by researchers. The results of the product feasibility test are presented in the **Table 3** and **Table 4**.

Table 3. Results of material expert validation

No	Assessment Indicator	Percentage	Description
1	Content Feasibility	85.25%	Very Valid
2	Presentation Feasibility	84.37%	Very Valid
3	PjBL and Critical Thinking Ability	86.36%	Very Valid
	Average	85.41%	Very Valid

Table 4. Validation results of media experts

No	Assessment Indicators	Percentage	Description
1	Feasibility of Graphics	89.10%	Very Valid
2	Feasibility of Language	91.66%	Very Valid
	Average	90.38%	Very Valid

The implementation and evaluation stage is the last stage of this development research, at this stage, product implementation, assessment of learning outcomes and student interest in the use of electronic student worksheets are carried out. The results at this stage are the results of the pretest and posttest as well as student responses which are presented in the following **Table 5** and **Table 6**.

Table 5. Results of pretest and posttest students

Group	Learning Outcome			Score Score n-gain	Category
	Min	Max	Average		
Pretest	0	50	18.5	0.37	Medium
Posttest	20	70	48.47		

Table 6. Results of student response questionnaire

Aspects of Assessment	Percentage	Information
Content	91.5%	Very Good
Language	90%	Very Good
Interests	92.57%	Very Good
Average	91.35%	Very Good

Discussion

This research and development aims to produce a teaching material product in the form of a virtual laboratory electronic student worksheets using PjBL to improve students' critical thinking ability. Electronic student worksheets was developed as a teaching material to

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support practicum activities carried out virtually/online. In line with research that Rahmi et al. (2018) by using worksheets as a guide in practical activities using a virtual lab to obtain good results and virtual laboratories are also an alternative to carry out practical activities if practical practice cannot be carried out directly. Electronic student worksheets is designed online by utilizing today's technology so that students can access it anytime and anywhere via a smartphone or computer/laptop. Ahmar & Rahman (2017) explained that the development of science and technology can affect students' perspectives in using the internet as the main goal and is always used in daily activities. Therefore the use of electronic student worksheets can contribute to the ease of students accessing learning anywhere and whenever.

The material in the development of electronic student worksheets is Faraday's law (electromagnetic induction), this material was chosen because it has room for virtual practicum on the *pHet* application and its applications are found in everyday life. Therefore, the researchers equipped the virtual laboratory electronic student worksheets with the PjBL model in order to improve students' critical thinking ability. Holubova (2013) mentions that the most important aspect in learning physics is its relationship with everyday life and can arouse students' curiosity about the learning material. The prepared electronic student worksheets are adjusted to PjBL indicators and critical thinking ability, so that the developed electronic student worksheets can meet PjBL criteria and critical thinking ability. The compatibility between each indicator in the electronic student worksheets is presented in the following **Table 7**.

Table 7. PjBL Indicator table and students' critical thinking ability in the developed electronic student worksheets

PjBL (Yulianto et al., 2017)	**Indicator Critical Thinking Ability Indicator (Ennis, 1985)**	**Activities in Electronic Student Worksheets**
Basic questions	Provide simple explanations	Students identify problems and find out what to do (activity 2)
Design product plans	Build skills basic	Students look for sources of information then determine and design what will be made (activity 2)
	Concluding	
Prepare a schedule		Students determine the schedule for making (activity 2)
Monitoring project activity and progress	Confidence	Project implementation

Testing Evaluation	Action	Presentation and project report making and concluding results (activity 3)

The advantages of this electronic student worksheets include: (1) students and teachers can access electronic student worksheets easily via smartphones, tablets, or computers/laptops; (2) students can fill in the results of observations directly in the available columns in each activity; (3) teachers can see the results of student work directly through notifications. Among these advantages, this electronic student worksheets still has many shortcomings including: (1) the quality of the resulting image is not clear so that there are some images and words that are not clear but can still be read; (2) there is still no assessment column for teachers in the electronic student worksheets so teachers still have to do the assessment manually; (3) electronic student worksheets can only be accessed with an internet connection, so if the connection is bad or even there is no connection, the electronic student worksheets cannot be accessed.

After the electronic student worksheets has been compiled, then a product feasibility assessment is carried out by validating the electronic student worksheets to validators, namely high school physics lecturers and teachers, providing student response questionnaires, and conducting effectiveness tests when carrying out learning using electronic student worksheets

The first time was expert validation based on 2 fields, namely the material/content field and the media field. Validation was carried out on 3 validators consisting of 2 lecturers and 1 high school physics teacher. Material expert validation consists of 3 assessment aspects, namely content feasibility aspects, presentation feasibility aspects, and the suitskills of electronic student worksheets with PjBL indicators and critical thinking ability. The results of the validation of material/content experts in each field get different values in each aspect, the content feasibility aspect gets a percentage value of 85.25% with a very valid category, the presentation feasibility aspect gets a percentage value of 84.37% with a very valid category, and aspects of the suitskills of electronic student worksheets with PjBL indicators and critical thinking ability obtained a percentage value of 86.36% with a very valid category. The overall percentage value in the material/content field obtained a percentage value of 85.41% with a very valid category. This statement is in accordance with the opinion Arikunto (2010) that electronic student worksheets is categorized as very valid if it obtains a percentage value on a scale of 78-100%. The validation of media experts consists of 2 aspects of the assessment,

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namely aspects of the feasibility of graphics and aspects of language. The validation results on the feasibility aspect of graphics obtained a percentage value of 89.10% and on the language aspect it obtained a percentage value of 91.66% with very valid categories in both. The overall value of the media field validation results obtained a percentage value of 90.38% with a very valid category, this is in accordance with the opinion Arikunto (2010) that the results of the electronic student worksheets assessment at a percentage of 78-100% obtained a very valid category. From the validation results that have been carried out, the electronic student worksheets can be declared valid and feasible to be tested with several improvements.

After being assessed by the validator, there are several suggestions and inputs that become evaluations for researchers to improve the content of the electronic student worksheets so that the quality of the electronic student worksheets becomes better. The suggestions and inputs include: (1) the material presented in the electronic student worksheets is incomplete in accordance with basic competencies and is not accompanied by pictures, adding pictures to the material can help students visualize the material more easily. This statement is in line with research (Lenzner et al., 2013), that combining text and images in learning can have a fairly good effect for students, the function of images as illustrations can improve understanding of complex learning materials; (2) add problem statement so that electronic student worksheets is more relevant in daily life. In learning physics, linking a concept with everyday life is very necessary so that students can more easily remember the material. This is in line with the opinion Mustari (2015) that through problem statements related to everyday life students can more easily determine solutions to the problems given and can distinguish which information is relevant from irrelevant in the statement of the problem; (3) there are several quantities that are not equipped with units; (4) on the cover there are letters that are piled up so that it is not clear to read; (5) there are some words that are not written correctly; (6) the location of the activity guide menu should be placed before the activity menu; (7) the *pHet* should be directly clicked on activity 1; (8) add an evaluation menu in the electronic student worksheets. The appearance of the electronic student worksheets after being revised is presented in the following **Figure 1**.

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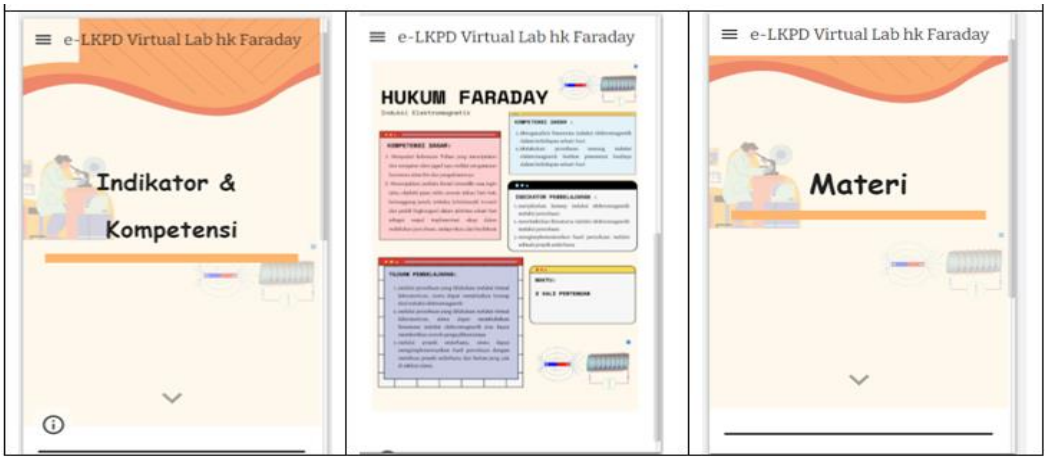

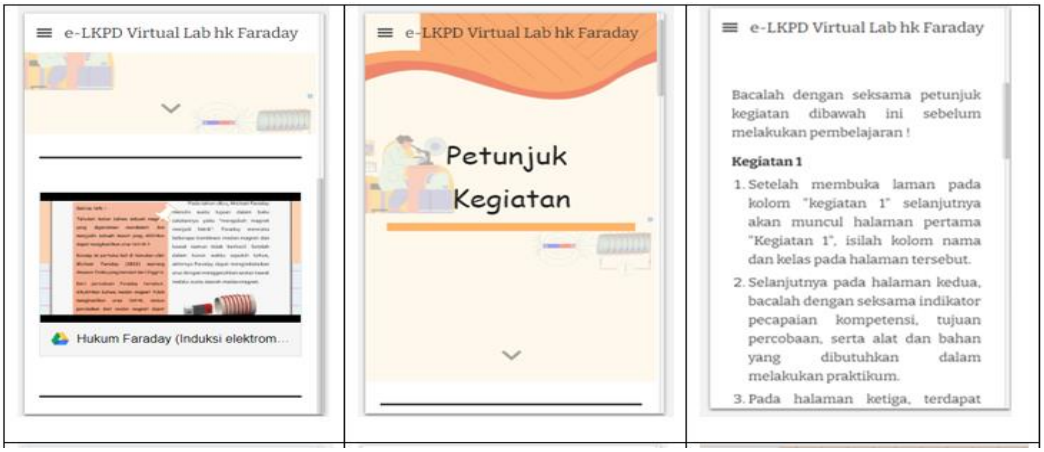

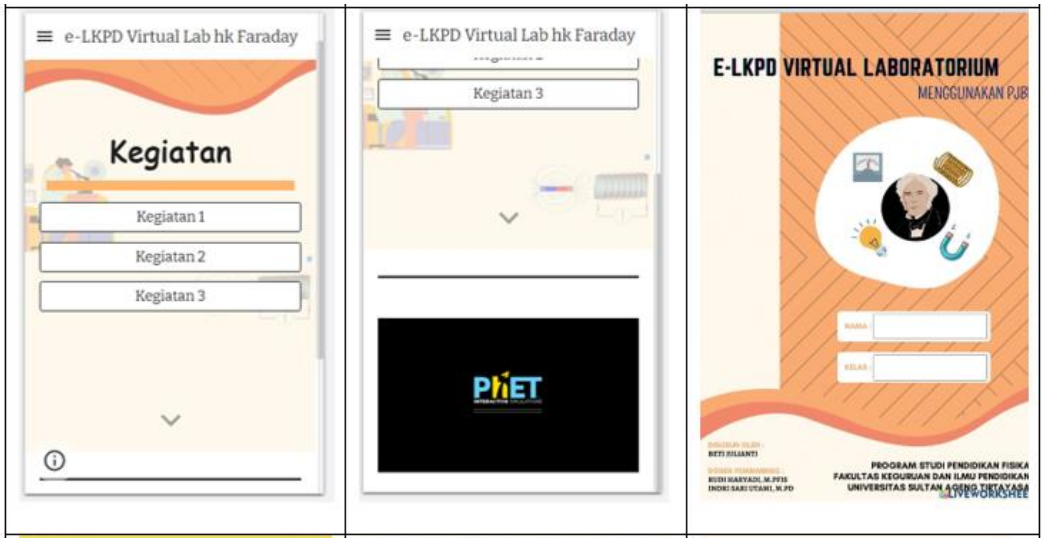

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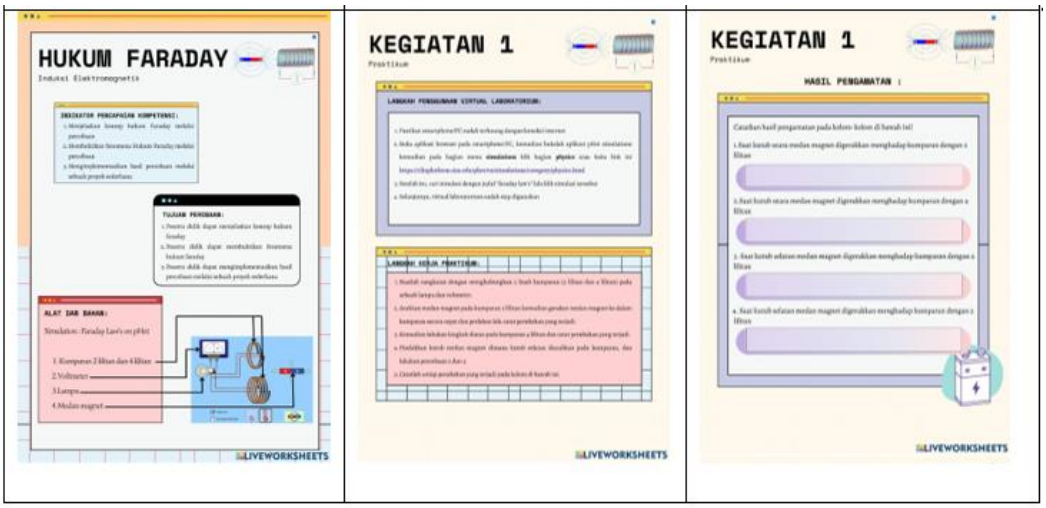

Figure 2. Display of the electronic student worksheets as a whole after being revised

Then, an effectiveness test was conducted to determine the effectiveness of the use of electronic student worksheets in improving students' critical thinking ability when learning in class. The effectiveness test was carried out by applying the electronic student worksheets in physics learning on Faraday's law material (electromagnetic induction) to 30 students of class XII science at Senior High School 1 Bayah for 3 meetings, adjusted to the activities in the electronic student worksheets which consisted of 3 activities. Activity 1 is the implementation of a virtual practicum using the *pHet*, activity 2 is making a simple project which is the implementation of PjBL, and activity 3 is a report on the results of making a project. Before learning begins, pretest with critical thinking ability test questions, totaling 10 items of description, this assessment is carried out to determine the students' critical thinking ability to the material of Faraday's law (electromagnetic induction). After that, learning is carried out by briefly explaining the material and continuing with the implementation of tasks in activity 1, namely the implementation of practicum through a virtual laboratory using the *pHet*. determine which projects to implement. The next meeting carried out making a project in groups, namely making a wireless charger, but at this stage students only succeeded in experimenting with the concept of a wireless charger. The last meeting was the presentation of the results of the project carried out in groups and the preparation of the reports contained in activity 3, and then ended with the implementation of the posttest to find out the final results of learning using electronic student worksheets.

The results of pretest and posttest were then analyzed using N-gain to determine the effect of the use of electronic student worksheets on increasing students' critical thinking

ability. From this analysis, students' learning outcomes obtained an N-gain of 0.38 in the moderate improvement category.

Next is the analysis of the results of student responses. The results of student responses were obtained after all processes from the implementation stage were completed, student responses were obtained from student questionnaire sheets which were arranged based on the content of the material, language, and student interest in the developed electronic student worksheets. Student response questionnaires were made as many as 17 statement items. Similar to the implementation of the effectiveness test, the student response questionnaire was filled out by 30 students who had previously carried out learning with electronic student worksheets. The results of student responses are divided into 3 aspects, namely the content of the material, language, and student interest in electronic student worksheets. The results obtained in the aspect of material content are 91.5% in the very good category, the language aspect gets a value of 90% in the very good category, and the interest aspect gets a score of 92.57% in the very good category. Of the three aspects, the interest aspect got the highest percentage score and the language aspect got the lowest score. This can be caused by the language conveyed in the electronic student worksheets is still too complicated so that it is difficult for students to understand. But overall, the development of the virtual laboratory electronic student worksheets using PjBL received a good response from students with an overall percentage score of 91.35% in the very good category.

Based on the results of the implementation of the electronic student worksheets on the effectiveness test and student responses, it can be concluded that the virtual laboratory electronic student worksheets using PjBL to improve critical thinking ability can improve students' critical thinking ability as evidenced by the results of the pretest students who have increased and the results of N-gain in the category moderate, and the results of student responses who get very good responses.

CONCLUSION

Based on the research that has been done, it can be concluded that the electronic student worksheets virtual laboratory using PjBL is feasible to use in learning physics in the classroom and can be used to improve students' critical thinking ability, this is in accordance with the results of expert validation who get a very feasible category, then the results of the

pretest and posttest of students who experienced an increase with an N-gain value obtained was 0.38 with a moderate improvement category, and the results of student responses with a percentage of 91.35% in the very good category. From these results, the researchers suggest that the virtual laboratory electronic student worksheets using PjBL can be used as alternative teaching materials for virtual practicum activities in the classroom, and can be redeveloped on different physics materials.

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