

## Implementing E-Learning-Based Virtual Laboratory Media to Students' Metacognitive Skills

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Irfan Yusuf, Sri Wahyu Widyaningsih <sup>(✉)</sup>  
Universitas Papua, Manokwari, Indonesia  
s.widyaningsih@unipa.ac.id

**Abstract**—The development of information and communication technology has penetrated various sectors, one of which is the education sector, especially in learning. The application of technology in the learning process is in the form of using virtual laboratory media to explain concepts that require a practicum, particularly in abstract materials. This study aims to determine students' metacognitive skills after applying the e-learning-based virtual laboratory media in physics experiment courses at the Department of Physics Education, Faculty of Teacher Training and Education, Universitas Papua. This qualitative research went through the stages of a lesson study. The data were collected from tests and questionnaires on students' metacognitive skills, observation sheets, interview guidelines, and video recordings during the open class. Further, the data were analyzed through Rasch modeling technique utilizing the *Winstep* application to analyze the students' metacognitive activity questionnaire after learning. The lesson study encompassed three stages of a series of activities, namely Plan, Do, and See. In the Plan stage, discussions were held with the lecturer team to develop learning tools in the form of chapter designs, lesson plans, and learning media. In the Do stage, the model lecturer performed the learning process based on the media that had been established. In the See stage, the reflection was done to examine the learning implementation carried out by the model lecturer in order to uncover weaknesses and strengths to be followed up on further learning. The results show that the quality of learning and students' metacognitive skills at each meeting are improved. It is proven by the good and very good category of the aforementioned results. To sum up, e-learning based virtual laboratory media are able to improve learning quality and develop students' metacognitive skills in the physics experiment courses.

**Keywords**—E-learning, lesson study, metacognitive skills, and virtual laboratory

### 1 Introduction

Using virtual laboratory media serves as one of the forms to implement Information and Communication Technology in classroom learning. Virtual laboratory media are among the solutions in overcoming the limitations of facilities and infrastructure as the supporting elements in the application of practicum activities (Flow-

ers, 2011; Wang, 2018; Yusuf & Subaer, 2013). Practicum activities are essential to be performed to give a conceptual understanding to students, specifically on physics material, which consists of everyday life phenomena (Almazaydeh, Younes, & El-leithy, 2016; Maulidah & Prima, 2018; Oidov, Tortogtokh, & Purevdagva, 2012). Students must be provided with a good understanding of the concept.

Teachers need to facilitate students to be able to learn. Online learning through e-learning can be the right solution to facilitate students in learning whenever and wherever they are (Fauzi, 2017; Sharpe, Rhona & Benfield, 2005; Yusuf, Widyaningsih, & Br.Sebayang, 2018). Currently, online learning can be employed through various applications, one of which is the Google Classroom developed by Google as a G Suite for Education feature released on August 12nd, 2014. Google Classroom is available online and free of charge (Madhavi, Mohan, & Didyanalla, 2018), and it presents materials and assignments as well as a means of online discussion. Virtual laboratory media can also be packaged into the Google Classroom application, making it easier for students to access and do experiments virtually. It is expected that using e-learning-based virtual laboratory media through the Google Classroom application is able to improve students' ability and understanding of learning, in which it can be realized if they can find out the way of learning.

The ability to discover how to learn and understand lessons is called metacognitive skill (Kallio et al., 2017). Metacognitive skills also play an important role in enhancing the quality of learning outcomes, because metacognition in the learning process has become the controller and monitor of students' way of thinking (Portilho & Medina, 2016; Tsai, Lin, Hong, & Tai, 2018). Metacognitive knowledge is the knowledge gained by students about cognitive processes, i.e., the knowledge that can be used to control cognitive processes. Metacognition is also related to the comprehension of how to reflect, make conclusions, and to be applied in practice (Amin & Mariani, 2017).

In physics experiment courses, metacognitive skills are related to the skills to solve problems based on experiments conducted. In problem-solving, students must have the ability to understand problems, simulate models, perform experimental procedures, and interpret solutions obtained (Ongowo & Indoshi, 2013). In improving the effectiveness of learning, lesson study activities are conducted to obtain reflections and make improvements at each meeting. The main focus of implementing a lesson study is the activity of students in the classroom, assuming that the activity is related to the teaching activities in the classroom (Saito et al., 2006). Therefore, it is expected that using e-learning-based virtual laboratory media through lesson study activities in the physics experiment courses can enhance students' metacognitive skills.

## **2 Method**

This qualitative research went through the stages of lesson study activities. The lesson study activities consist of three stages of a series of activities, including Plan, Do, and See (Saito et al., 2006). During the Plan stage, there was a discussion with the lecturer team to develop learning tools, such as chapter designs, lesson plans, and

learning media. Further, in the Do stage, learning is done by the model lecturer based on the tools that had been prepared. In the See stage, on the other hand, a reflection was carried out to study the learning process implemented by the model lecturer to reveal weaknesses and strengths to be followed up in the next learning process.

The subjects in this study were students of the Department of Physics Education, Faculty of Teacher Training and Education, Universitas Papua, who programmed 14 physics experiment courses. The research data were collected from students' metacognitive skills tests which were given after the learning process, observation sheets, interview guidelines, and video recordings during the open class. The data of metacognition comprised ten open-ended questions and a questionnaire on metacognition. Open-ended questions were presented in a written form to allow students to express their ideas, cognitive strategies, along with the time and reasons for applying the strategies. The contents were linked with the concept of modern physics experiments, which were included in a virtual laboratory. The category of students' metacognitive skills obtained was based on the open-ended questions, as provided in the following Table 1 (Riduwan, 2011).

**Table 1.** Student metacognition ability category

Interval Class	Category
81-100	Very good
61-80	Good
41-60	Moderate
21-40	Poor
<21	Very poor

The questionnaire of students' metacognitive skills assessment was based on the indicators of metacognition, as given in Table 2 below (Schraw, 1998). The data of the questionnaire regarding students' metacognitive activities after learning were analyzed through the Rasch modeling technique utilizing the Winstep application.

**Table 2.** Indicators and aspects of metacognitive activities

Metacognitive Activities	Indicators	Descriptions
Planning	Understanding problems	Thinking about how to understand the problems
		Thinking about reading the problems more than once
		Thinking about how to gain information that is known and asked by the given problems
	Thinking about representations and recalling the prerequisite material that can help complete the task.	Thinking about how to model the problems in the form of images
		Thinking about how to give a notation, a symbol on the image modeling
	The employed problem-solving strategies	Thinking about the prerequisite concepts when reading questions
		Recalling the idea of whether or not the problems had been solved once before

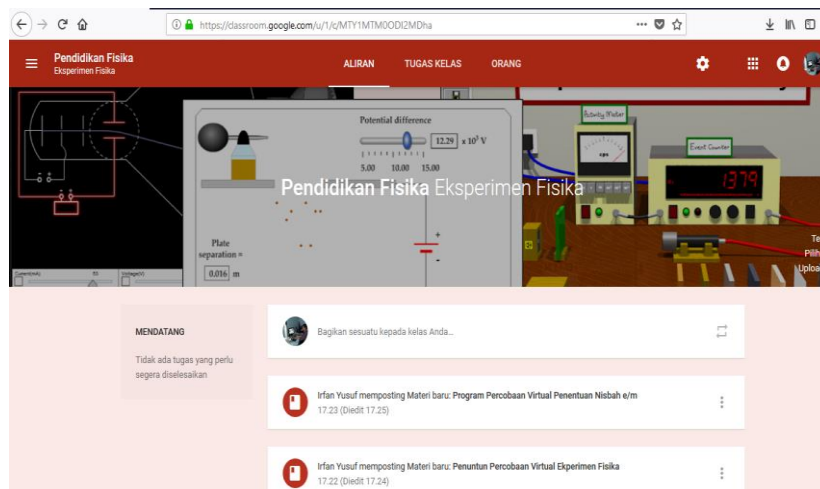
Metacognitive Activities	Indicators	Descriptions
		Thinking about how to arrange the steps to solve the problems
		Thinking about strategies or different ways to solve the problems
Monitoring	Controlling the implementation of problem-solving activities	Thinking about checking the suitability of the notation, the symbol used from the known information
		Thinking about checking the suitability of the prerequisite concept (e.g., the concept of a virtual experiment material) used to solve the problems
		Controlling the calculation accuracy step by step
		Thinking about checking every step of the completion and giving a checklist to the section that has been checked.
Evaluating	Improvement strategy if there is an error	Thinking about repeating several steps if an error occurs.
		Thinking about trying another way, if an error occurs.
	Evaluating the obtained results	Thinking about how to check the suitability of the answer to the question
		Thinking about how to re-check the applied way to ensure that the answers are correct.
		Re-thinking about whether or not the answers are new.
	Evaluating the ways/strategies applied to solve problems	Thinking about whether or not the applied way can also be applied to other problems
Thinking about other ways that can be used to solve problems.		

### 3 Results and Discussion

The application of experimental physics learning is performed through e-learning-based virtual laboratory media, given the limitations of facilities and infrastructure in the Laboratory of the Department of Physics Education, Universitas Papua. The physics experiment courses consist of modern physics experiments that describe abstract physics concepts so that students should be given an understanding of doing experiments by using virtual laboratory media.

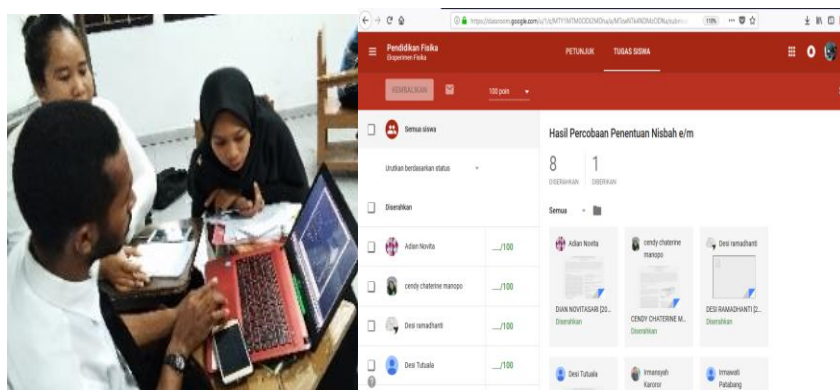
The virtual laboratory media used in physics experiment courses are presented in an integrated form with the e-learning online learning system through the Google Classroom application. Teachers can easily create online classes and provide various materials and assignments through the classroom.google.com website address (Joy et al., 2018). Teachers and students can also run online classes on their smartphones through the Google classroom application for Android. Google classroom application makes it easy for students to learn (Heggart, Yoo, & Heggart, 2018). They can access any lecture completeness, including details of materials, virtual laboratory media, experiment guidelines, or collecting assignments online. Learning to use e-learning

allows students to learn whenever and wherever they are (Hooks & Casarez, 2018). Figure 1 shows the e-learning-based virtual laboratory media display through the Google classroom application.



**Fig. 1.** Display of e-learning consisting of virtual laboratory media

At the beginning of the lecture, the model lecturer conveys a general description of the material, gives motivation, and appreciation about the experiment to be conducted. Students are divided into five groups, and each group consists of three people. They work together in a virtual experiment, as well as retrieves observational data. Figure 2 presents the virtual trial process carried out in groups and their activities in the online classroom through the Google Classroom application.



**Fig. 2.** Students' learning activities through virtual laboratory media and through e-learning

In the first experiment, the determination of the  $e/m$  ratio, the students regulate the changes in voltage and electric current, which also cause changes in the radius of

the electron beam. Students can determine the spread of the  $e / m$  ratio through the observations obtained. Each group is assigned to record their measurement results and write them down on the worksheets that have been provided. Besides, each student is assigned to make an experimental report following the format of research article that consists of abstract, introduction, method, results and discussion, conclusions and suggestions, and references. In the next meeting, group discussions are held. One group presented the results of their experiments. The results show that several measurement values of the  $e / m$  ratio that they obtain are not much different from the theory. However, some data are in contrast with the theory. In addition, students discuss the results of their experiments. Some students seem enthusiastic about asking questions and giving answers regarding the problems faced. In the See stage, the determination of the  $e / m$  ratio is obtained, in which each group actively does the experiments. They control changes in voltage and electric current, and further see changes in the radius of the electron beam that is formed. Cooperation is very clearly seen, especially the number of members in the group is not large (three people) so that each student in the group can do their job effectively. Nevertheless, several students are not too engaged, e.g., student number 2 in group 4. The student still finds it challenging to control the measurand contained in the virtual laboratory media. The model lecturer provides group guidance to make the students be able to do experiments and to have the results of observations based on the experiments conducted.

During the Millikan oil-drop experiment, students observe the movement of electron particles to determine the charge. They work together on retrieving the data. Some of them control the simulation, calculate the travel time of electron particle movements, and some record the observations obtained. They are also taking turn in data collection. In this experiment, the data retrieval processes are repeated in order that the students need to be forbearing and conscientious. Moreover, in the See stage, it is revealed that most of the students have shown better activities in doing experiments than the previous ones. They also tend to be more cooperative with each other in collecting data.

In the implementation of radioactive activity experiments, students are required to be more creative since many variables are observed. Students measure the number of counts produced by each radiation source to determine its activity and its penetrating power based on the type of barrier that exists. They also must understand the principle of the experiment because the experimental steps do not accompany the worksheet provided. Besides, they need to be creative in finding practical ways to get the expected data. In the See stage, it is obtained that students are enthusiastic during the learning process, involved in the discussions, and can describe their experiments with great results.

As found in the implementation of learning activities, students are active during the virtual experiment. Some students take turn in collecting data, controlling responses, doing observations, and recording the experiment results. Collaboration among the students during a virtual experiment is well-established (Kurniawan, Mujasam, Yusuf, & Widyaningsih, 2019), because the virtual experimental device encompasses a worksheet that requires students to do experiments creatively, and determines the steps to be taken to gain the observed data (Kabiri & Wannous, 2018; Wu, 2018;

Yusuf & Widyaningsih, 2019). This condition can encourage students to learn together and to be responsible for the materials in order to achieve common goals. Shared learning opens opportunities for them to be more courageous in discussing and being responsible in the learning process (Elas, Majid, & Narasuman, 2019; Liu, Li, & Zhang, 2018; Widyaningsih & Yusuf, 2019). Moreover, the reflections at each meeting indicate that the discussions give an excellent academic atmosphere. Some students actively ask questions, and the other answers them. The model lecturer as the learning facilitator provides opportunities for each student to present the results of the experiment and analyze the data they have collected.

Online learning is also undertaken to facilitate students in accessing materials and experiencing studying on other platforms besides in the classroom. Discussions are also available in online classes, where the students enthusiastically ask questions and discuss the materials. Online discussions make it much easier for students to have information because they can immediately get the actual answers through discussions between teachers and students (Lee & Martin, 2017), and to give their assignments on time. Lecturers can directly give scores of students' assignments, and the students can immediately see their scores through their accounts (Anthony G. Picciano, 2002).

The use of a lesson study in the learning process also has a good impact on improving the learning quality. The model lecturer gains information about the learning atmosphere and condition, so that s/he is able to make an improvement at each meeting (Skultety, Gonzalez, & Vargas, 2017). Lecturers' teaching professionalism can also be enhanced by considering the suggestions and criticisms from various observers, which are then collaboratively and continuously analyzed (Hasanuddin & Akhadiah, 2019; Sarimanah, 2018).

At the end of each discussion unit, students' metacognitive skills are assessed. The measurement of metacognitive skills is intended to find out their understanding of each experiment. Test results for metacognitive skills are shown in Table 3.

**Table 3.** Frequency distribution of students' metacognitive skills in every topic of the experiments

Interval Class	Frequency			Category
	<i>Determination of e / m ratio</i>	<i>Millikan Oil Drops</i>	<i>Radioactive Activities</i>	
81-100	0	2	3	Very good
61-80	12	11	11	Good
41-60	2	1	0	Moderate
21-40	0	0	0	Poor
<21	0	0	0	Very Poor
Total	14	14	14	
Min	50,0	60,0	65,0	
Max	80,0	86,0	87,0	
Average	70,0	73,6	75,4	
SD	8,1	7,3	7,6	

Table 3 signifies that students' metacognitive activities have increased in each unit of the experiments performed, proven by the increase in the average values and meta-

cognitive assessment categories. In the first experiment, the determination of the  $e / m$  ratio arrives at an average value of  $70.00 \pm SD 8.1$ , good category. No students reach very good grades due to the unfamiliarity of such a new learning implementation. Moreover, in the second experiment, the Millikan oil-drop experiment reaches an average value of  $73.4 \pm SD 7.3$ , good category. Eventually, there is an increase in metacognitive skills, by which two students are in a very good category.

Similarly, radioactive substance activities as the third experiment get an average value of  $75.4 \pm SD 7.6$ , good category. This experiment also experiences an increase in students' metacognitive skills, where they mostly arrive at good and very good categories. The improvement of students' metacognitive skills is shown at each meeting, e.g., they can understand how they can obtain the expected measurement results. Metacognitive skills show students' deep understanding of how they acquire knowledge (Garrison & Akyol, 2015; Lai, Zhu, Chen, & Li, 2015). The skills refer to ways to raise awareness about the thinking process in on-going learning. If this is true, then one can begin to think about designing, monitoring, and assessing what s/he learns (Sarimanah, 2016).

Assessment of metacognitive skills is done through questionnaire responses to student activities given at the end of the learning activities. The results of the questionnaire can be viewed in the following Figure 3.

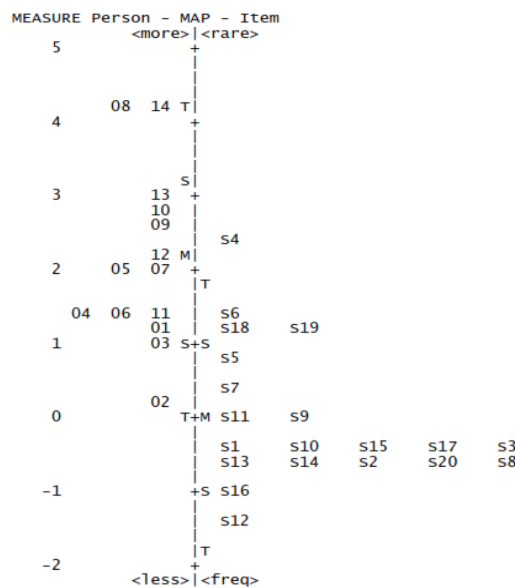


Fig. 3. Analysis of the assessment of metacognitive activities responses

Figure 3 brings out the fact that on the left side, there are five out of 14 students who have a high level of skill, i.e., agree with all statement items in the questionnaire. On the right side, there is one of the most difficult statements to agree, namely S4 "thinking about how to model problems in the form of images". This is caused by the



trouble faced by the students in analyzing experimental data, and they do not model the analysis in the form mentioned previously. This issue can be immediately overcome by utilizing numeric processing programs, such as Excel. Students can instantly input the value of the measurand obtained through the experiment, and then enter the equation formulation to obtain the measurand sought.

The statement that is mostly agreed by most of the students is S12 “controlling the calculation accuracy systematically”, indicating that the difficulty they experience in analyzing data makes them more careful in doing the calculation step by step (Özsoy & Ataman, 2009). On the right side of the map, it is clearly seen that the majority of the students agree with the provided statements. Therefore, their metacognitive activities can be developed through learning. Metacognitive activities are related to the responses of the students who are good at understanding the subject matter (Bol, Campbell, Perez, & Yen, 2016; Richmond, Bacca, Becknell, & Coyle, 2017).

## 4 Conclusion

The implementation of e-learning-based virtual laboratory media can improve the learning quality and students' metacognitive skills in physics experiment courses through lesson study activities. In the first experiment, the determination of the  $e/m$  ratio measures at an average value of  $70.00 \pm SD 8.1$  or good category. In this experiment, no students reach very good grades. Further, in the second experiment, the Millikan oil-drop experiment reaches an average value of  $73.4 \pm SD 7.3$ , good category. Radioactive substance activities as the third experiment, on the other hand, get an average value of  $75.4 \pm SD 7.6$ , good category, where the students mostly arrive at good and very good categories. The questionnaire results regarding metacognitive activities signify that the majority of the students have good responses to their learning, and their metacognitive skills can be developed.

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## 6 Authors

**Irfan Yusuf** and **Sri WahyuWidyaningsih** are currently working at the Faculty of Teacher Training and Education in Universitas Papua, Manokwari, Papua Barat, Indonesia. Irfan Yusuf is the Editor-in-Chief of the *Kasuari: Physics Education Journal (KPEJ)* at <http://journalfkipunipa.org/index.php/kpej>.

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