International Journal of Evaluation and Research in Education (IJERE)
Vol. 11, No. 1, March 2022, pp. 385~391
ISSN: 2252-8822, DOI: 10.11591/ijere.v11i1.21737

A task model for supporting virtual laboratory based on inquiry skills, social and scientific communication

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Article Info

Article history:

Received Jun 7, 2021
Revised Jan 2, 2022
Accepted Feb 4, 2022

Keywords:

Inquiry skills
Scientific communication
Social communication
Task model
Virtual laboratory

ABSTRACT

Comprehensive monitoring in virtual laboratory learning needs a task model. This model was design based on inquiry skills, social and scientific communication of prospective physics teachers. The development of these three skills is still a problem in recent research on virtual laboratory learning. This research was research and development (RD) using a preliminary study (literature studies, field surveys, and preparation of the initial product) and development of the model (within limited testing). Respondents were 54 prospective physics teachers and five physics lecturers from several universities in Indonesia. The analysis was done by descriptive qualitative, and quantitative. There are two essential parts of the task model. The first part consists of six inquiry steps, which describe the interactions between students with their virtual experiments. The second part consists of three inquiry steps that analyze how students communicate their virtual experiments through verbal, picture, and diagrammatic representations. Based on these findings, the task model's design is essential to develop inquiry skills, social and scientific communication for prospective physics teachers. The researcher can use this task model in the next step of RD.

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1. INTRODUCTION

Information technology and computers have developed so rapidly and have tremendous influence. Students and teachers can feel the implications in learning media development assisted by computers and the internet. Continuous multimedia innovation finally gave birth to a virtual laboratory to support practicum activities that run conventionally [1]. This virtual laboratory can provide opportunities for students specifically to do practicum either through or without internet access so that students do not need to be present to attend lab work in the laboratory.

Laboratory activities are crucial in learning physics. This activity aspect of the product, process, and learning attitude can be further developed [2]. Designing laboratory activities cannot be separated from inquiry activities [3]. Inquiry-based learning involves students physically and mentally to solve problems[4], [5]. However, several studies mentioned that Indonesian students relatively often used memorization and practice strategies [6]–[8]. The role of students tends to receive and use knowledge, not inspiration or collaboration [9]. At the university level, some findings suggest that the form of learning and assignment approach significantly affects the inquiry skills of prospective physics teachers [10], [11]. The implications of these findings are to consider how best to support teacher candidates in teaching physics as inquiry. Inquiry learning that emphasizes deep processing, critical thinking, and active learning is always challenging for Indonesia's learning system, especially in its laboratory activities.

Several studies have shown the effectiveness of virtual laboratory in increasing student interest and involvement [12]–[14] as well as improving learning achievement [12], [15]. However, learning with virtual laboratory needs to be considered in increasing student inquiry abilities, not just learning achievement or interest in learning. Some researchers also report some student difficulties when organizing their knowledge [16], [17]. For this purpose, assignment and mentoring are the best ways to help students in this virtual learning. Therefore, developing an effective form of study in learning with a virtual laboratory is critical to help prospective physics teachers improve their inquiry abilities.

The teacher must also learn to "do" science in the real world as the ability of inquiry. Therefore, it is necessary to provide activities such as discussion, writing ideas, and making presentations to communicate with others [18]. Universities must do teaching social and scientific communication in learning [19] [20]. Social skill occurs when students can communicate well with their peers. Social skills will manifest in group work when channeling ideas to answer problems through communication between students. The use of technology in the laboratory has built a positive attitude from students towards laboratory learning [21]. In a systematic review of virtual laboratories 2009-2019 found that most of the perspectives of virtual laboratories were to provide instruction without interaction, exploration of individual experiences, the role of the environment in providing social learning was lost [22]. However, it is also a finding that there is still a need to develop communication assistance both in the implementation and in the delivery stage of laboratory experiment results. If the student met these requirements, then the use of technology can give positive results. Other studies have found that activities designed around a framework such as the Kolb model are more effective at increasing interest in learning experiences [23]. The interaction between students is an essential factor that determines student learning experience.

Based on this review, three aspects (inquiry, social, and scientific communication) are used in compiling a task model in a virtual laboratory. The laboratory learning goals of National Research Council (NRC) 2006 and eight crucial scientific and technical practices from NRC 2012 are the basis of the development of these three aspects [12]. This study aimed to get a preliminary study and design of the task model through a virtual laboratory. The analyses referred to the inquiry skill, social and communication skills of a prospective physics teacher.

2. RESEARCH METHOD

The research design used refers to the research and development (RD) design of Borg and Gall, modified. Research and development in education related to developing and validating educational products [24]. The educational product referred to in this study is the assignment model. The design of the RD includes four stages, namely a preliminary study, model design, model development, and model validation.

This research was a part of RD, which is a preliminary study stage and model design. Preliminary study consists of literature study and field study. The literature review includes gathering information related to the literature that supports the development of an assignment model in a virtual laboratory. Field studies are activities carried out to find problems related to learning virtual physics laboratories at universities, inquiry, social and communication skills of students as prospective physics teachers. Field studies were carried out by conducting learning observations, distributing questionnaires, and interviews with physics lecturers. Table 1 summarizes data collection techniques on each aspect.

The method used is the descriptive method to describe systematic, factual, accurate, and what they are. Researchers can directly relate to respondents and other objects related to the problem under study. At this stage, respondents were 54 prospective physics teachers and five physics lecturers from five universities in Indonesia (one university in Sumatra, three universities in Java, and one university in Papua).

Table 1. Research data collection technique in preliminary study stage

Aspect	Data collection	Respondent
Use of virtual laboratory	Questionnaire and interview	Prospective physics teachers and lecture
Material characteristics and task model	Literature study and interviews	Lecture
Use of inquiry in the laboratory	Interview	Lecture
The ability of inquiry prospective physics teachers	Questionnaire	Prospective physics teachers
Social and communication skills of prospective physics teachers	Questionnaire	Prospective physics teachers

The instrument used in this study is a description and is the result of an adaptation of the existing inquiry, social and communication ability measurement instruments. From the existing instruments, the researcher then developed it again by arranging 12 items according to the indicators to be achieved. The instrument was then validated in terms of content and language by involving the help of three experts (expert judgment). From the results of the second validation, the expert stated that eight questions were declared valid in terms of content and language and suitable for research. The distribution of test items is presented in Table 2.

The assessment of inquiry, social and scientific communication skills use four categories, namely: 1(bad); 2 (sufficient); 3 (good); 4 (very good). The analysis used descriptive qualitative and quantitative approaches. The qualitative description referred to the results of literature studies and interviews. In comparison, the quantitative description employed the results of the questionnaire respondents with percentage analysis. At the stage of model design consist of an analysis of the virtual laboratory learning stages, assignment models, student activities and forms of assessment is carried out. At the end of this stage, the design of the assignment model will be presented in the form of stages of model implementation, lecturer and student activities.

Table 2. Percentage of the student in inquiry skills

Aspect	Indicator	Number of questions
Inquiry skills	Asking questions	1, 2
	Developing and using models	3, 4
	Planning and carrying out investigations	5
Social and communication skills	Obtaining evaluation	6, 7
	Communicating information	8

3. RESULTS AND DISCUSSION

3.1. Preliminary results

The questionnaire results consisted of ease of access, the virtual laboratory simulations, and the evaluation of the use of the virtual laboratory. Table 3 presents the results of the respondent questionnaire. The table shows that the ease of access and using free virtual lab simulation is the desire of most students and some lecturers. This data presents that the virtual lab's role is more on the convenience of using the same as simulations in general. A virtual laboratory is essential to instill concepts in which preparation, display the performance, and evaluation of the experimental procedure [12]. However, based on the interviews' results evaluating the implementation of a virtual laboratory, students are stuck on the virtual laboratory display and still have difficulty finding concepts.

Table 3. Questionnaire results from the use of virtual laboratory in learning

Indicator	Respondent	
	Lecture	Prospective physics teacher
Ease of access	50% offline	84% offline
Virtual labs simulation	55% use free simulation 45% develop their own simulation	87% use free simulation
Evaluate the implementation of the Virtual lab	Difficulties in monitoring implementation	Requires direction in data analysis It makes the practice more fun, but they still cannot find the concept of this practice

In cognitive theory, human working memory can only handle a limited amount of information [25]. Various inputs and interactions can cause high cognitive loads [26]. The inherent virtual laboratory features and design can solve students' intrinsic cognitive load. Some researchers have found that students' conceptual understanding in virtual laboratory outperforms students in physical laboratories [6], [27]. Nevertheless, when evaluating the effectiveness of virtual lab, the focus is on learning achievement and acceptance or preferences of teachers and students to use it and students' ability and reasoning patterns. For this reason, in developing the task model, it is necessary to accommodate the skills and patterns of student reasoning, steps of inquiry as to the spirit of the laboratory, and communication interactions between students and lecturers.

Inquiry learning refers to instructional approaches and curriculum material for students to learn science and scientific ways to learn [5]. In this aspect, the researcher used interviews with five lecturers about the inquiry stages conducted in learning, especially in the laboratory. The purpose of this interview is to get an assignment form with an inquiry model that suits a virtual lab. Questions based on the learning stages of the inquiry levels include discovery learning, interactive demonstrations, inquiry lessons, inquiry labs, real-world applications, and hypothetical inquiry [28], [29].

There was a high implementation of inquiry in the laboratory from the interview, but there were still many problems. Students are very dependent on the practicum handbook. Their analysis used tends to be based on the books referenced and no data exploration. An inquiry-based curriculum allocates about 50% of the time for laboratory activities [30]. However, some research shows that the laboratory activities developed are still verification in nature [30], [31]. For example, they prove the concepts or principles previously discussed with lab activities that are still teacher-centered. Practical activities like this are not able to develop students' thinking ability skills in a higher stage. The other finding from the interviews, there was still a need for structured guidance in assignment to both the real laboratory and the virtual laboratory.

In addition to guiding the implementation of virtual laboratories, this assignment model's design also aims to practice inquiry skills, social and scientific communication. In this preliminary study, the researcher also sought the prospective physics teachers' initial conditions or abilities. The aim is that the assignment model is in line with the development goals. Table 4 and Table 5 explain the preliminary data about inquiry skills and social and scientific communication.

Table 4. Percentage of the student in inquiry skills

Indicators of inquiry skills	1	2	3	4
Asking questions	-	25	43	31
Developing and using models	17	31	30	22
Planning and carrying out investigations	24	42	18	15

Table 4 shows that inquiry skills in planning and carrying out investigations were lower than another indicator. This indicator includes students' ability to make hypotheses and make plans to convey the results of the investigation [12]. Some studies also report some of the difficulties students face when self-regulating their learning [32], [33]. These findings form the basis for the preparation of the task model. Teachers must guide according to the conditions of the student's needs and in different forms of guidance. Suppose students have difficulty composing their hypotheses. In that case, it is necessary to provide a scaffold to make hypotheses from various concepts.

From our previous research, indicators communicating can be describing pictures or empirical data and then changing it in other forms such as sentences, diagrams, graphs [4], [34], [35]. Based on the data analysis results, the value for communicating information 48% has a good score while obtaining evaluation indicators get 33% good category as seen in Table 5. This information is in line with the findings in several studies on social interaction in collaborative learning. That interaction is more often related to group work coordination, such as planning and organizing [33], [36]. Meanwhile, task-related interactions are mostly in individual comments [8], [36].

Table 5. Percentage of the students in social and scientific communication skills

Indicators of social and scientific communication	1	2	3	4
Obtaining evaluation	7	33	31	28
Communicating information	-	17	48	35

3.2. Design task model

In the virtual learning process, guidance is a means to support self-regulated learning by students. Based on preliminary results, we design a task model with two essential parts. The first part is to describe the interactions between students with their virtual experiments. The second part analyzes how students communicate their virtual experiments through verbal, picture, and diagrammatic representations. Table 6 describes the task model in virtual learning.

Discussion activities that include communication and reflection can occur in each phase during inquiry-based learning. They connected the issue to all other phases. So that, discussions can occur at any time during inquiry learning or after inquiry-based learning (reflection). In the first part, the task model was focused on the interaction between students and virtual experiments. Although implemented independently by students, lecturers must provide concept points investigated through referral questions. This activity has two functions. First, it is to know the initial concept and whether a misunderstanding occurs or does not understand the concept [10]. Second, it is useful in providing social learning through the inclusion of teachers and peers [22]. The essence of the paradigm shift in contextual learning (CTL) is the attempt to uncover what students think about the problem [37], talk about misunderstandings that occur [37], [38], and direct them to readjust their ideas [11].

Based on the literature review, the five frequently used inquiry phases are grouped into three parts [39], [40]. The first part, conceptualization, has two phases, namely making questions and answers and hypotheses. The second part is investigations in the form of exploration or experiments that lead to data interpretation. The third part is a discussion divided into two phases, reflection and communication. After focusing on interaction, the second part is to analyze how students communicate their results through representations. Students have to analyze and observe the error in the first to the second experiment. Students can interpret it in their representation like a verbal, picture, and diagrammatic. This step was to from preliminary results we found that communicating information is better than obtaining evaluation. The lecturer's role in this step is to direct science and social communication in the way students represent the results of their investigations. In this step, students have the freedom to represent results. The form of interaction during collaborative learning in virtual learning highlights the importance of group activities and socio-emotional issues [41]. In another research was found that different types of technology can influence the form of interaction [36].

Table 6. Task model in virtual learning in correlation with inquiry step dan students' activities

Part of the task model in virtual learning	Inquiry step	Students' activities
Describe the interactions between students with their virtual experiments	Goal setting	Students set their own learning goals for the laboratory.
	Concept review	Students review a physics concept by responding to the eight questions presented as paragraphs.
	Establish experimental investigations and identify variables	Students create experimental questions to investigate relationships and identify variables.
	Planning	Students make several essential decisions without experimental design.
	Experiment	Experimentation tests done and recorded data.
	Evaluate, design, and improve experiments	Students evaluate the possibility of experimental weaknesses, design improvements, and then improve experiments.
Analyze how students communicate their virtual experiments through representations such as verbal, picture, and diagrammatic.	Analyze errors	Students analyze and observe whether errors increase or decrease from the first experiment to the second experiment,
	Interpret the results	Students interpret the results of experiments in their way.
	Design new experiments	Each student promotes a new research question and designs a new experiment to answer the question.

4. CONCLUSION

The task model design is essential to develop inquiry skills, social and scientific communication for prospective physics teachers. Preliminary results found that the virtual lab's role is more on the convenience of use. There was still a need for structured guidance in assignment to both the real laboratory and the virtual laboratory. A task model is divided into two parts to support self-regulation learning. The first part is to describe the interactions between students with their virtual experiments. The second part analyzes how students communicate their virtual experiments through representations such as verbal, picture, and diagrammatic. The researcher can use the implementation of this task model in the next step of R&D, model development and model validation.

The results of this study are from a limited respondent. However, it is sufficient to replicate this study at different times under the same analytical conditions. Research would also be interesting if it could increase the number of participants, as well as the degree of heterogeneity. On the other hand, future virtual laboratory research should also be based on an analysis of learning styles, learning perceptions, motivations and student expectations.

ACKNOWLEDGEMENTS

This research was funded by the Institute of Research and Community Service of Universitas Muhammadiyah Purworejo. This research is also supported by team from Central Laboratory Department of Physics Education, Universitas Muhammadiyah Purworejo.

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