Virtual laboratory as a media to improve the conceptual mastery of molecular biology

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Abstract. The development of computer processing capabilities has implications for science learning. Various computer simulations are designed as tools or media to improve the mastery of science concepts. Virtual laboratory is one computer software that contains controlled experimental simulations. This weak experimental research uses one-group pretest-posttest design, which is observation or measurement carried out on one group of subjects before and after a treatment. The research subjects were 28 students of Biology Education at one of the educational institutions in the Kota Pekanbaru who contracted elective course in Molecular Biology in the even semester of Academic Year 2017/2018. The treatment in this study is the use of virtual laboratory integrated in the free inquiry learning strategy. The concept of Molecular Biology assessed was Polymerase Chain Reaction (PCR). The test instrument to assess the mastery of the PCR concept is multiple choice questions with four answer choices. The results showed that the majority of students (82.8%) increased their mastery of the concept with a low criterion (N-gain score = 0.23), and on average 93% of students gave positive responses to learning with the virtual PCR experiment on the PCR concept, and 7% of students gave negative responses. It was concluded that the virtual laboratory can improve the concept mastery of PCR with low criteria.

1. Introduction
Molecular Biology is a branch of Biology which is based on a number of disciplines, especially Biochemistry, Cell Biology, and Genetics. The complexity of the concepts discussed in Molecular Biology requires detailed review, adequate laboratory techniques, and learning strategies that can accommodate mastery of concepts. Conceptual mastery of molecular biology can be supported by the availability of laboratory facilities to provide opportunities for students to experiment. In general, science learning cannot be separated from the existence of a laboratory. According to [1] the laboratory is a potential motivator for science students. Ideally, in the laboratory students can be actively involved in the science process, use scientific methods, and have plenty of time to experiment with tutor guidance. However, this ideal condition is often not fulfilled because of the reason that the cost is large enough to complete laboratory facilities.

In line with the development of computer processing capabilities, the limitations of science laboratory facilities can be found an alternative solution. Various science experiment simulations are...
designed as tools or media to improve mastery of scientific concepts. Virtual laboratory is one of the computer software that contains controlled experimental simulation, which allows the user to carry out scientific investigations with little cost, a high level of safety, and more time-saving compared to hands-on laboratory activities [2]. According to the [3] virtual laboratory is an interactive simulation of experiments, where all manipulations are carried out on a computer. [4] argues that the virtual laboratory was developed as an effective computerized learning tool that can replace real laboratories for conducting ordinary experiments and demonstrations, which are supported by various learning technologies such as simulations, animations, and videos that facilitate user interaction. One of the most important characteristics of a virtual laboratory is its high flexibility that facilitates students to learn independently, anytime, and anywhere. According to [5] the virtual laboratory allows students to understand the basic principles and theories behind laboratory experiments. This technology avoids the use of biological and chemical materials that are expensive, dangerous and toxic to students and the environment.

However, at the same time there are demands to develop traditional inquiry skills such as hands-on laboratory activities [6]. This hands-on laboratory activity is important for students to hone their science process skills. Modern sciences learning requires students to inquiry, not only hear and repeat the correct answers during the learning process. The inquiry process begins by gathering information and data using sensory abilities, such as observing, hearing, touching, tasting, and other physical activities. The inquiry process is a way for students to construct their knowledge through interaction with various learning sources. Inquiry learning is an innovative research-based learning strategy that brings inquiry and discovery activities into the classroom learning environment. According to [7] and [8] inquiry includes the decision-making process of verification of experimental results that are scientifically controlled, debated, and discussed among students. Characteristics of free inquiry learning is that students formulate their own problems, connect their learning with prior knowledge, and work collaboratively by sharing and discussing with peers so that students are intrinsically motivated to learn [9]. [10] argue that teaching strategies with inquiry show a significant and important influence on learning achievement.

Based on the description above, the teaching designers and practitioners tries to develop effective learning strategies that can combine sophisticated computerized technology with hands-on laboratory activities. Therefore, this study aims to develop a PCR virtual laboratory program that facilitates student activity to conduct PCR experiments even though virtually, and then the PCR virtual laboratory program is integrated in learning free inquiry.

2. Method
The research design used is one-group pretest-posttest design. This design is part of weak experimental designs [11] or pre-experimental designs or nondesigns [12]. The research subjects were 28 students (1 male and 27 female) of Biology Education in one of the Institution of Teacher Training and Education in Kota Pekanbaru. The concept discussed were Polymerase Chain Reaction (PCR) in the Molecular Biology elective courses.

The learning strategy used is free inquiry. Learning activities begin by giving the pretest consisting of 21 multiple choice questions with four answer choices about the PCR concept. After that the lecturer explained the final achievement of the expected learning and the implementation stages of the free inquiry strategy. The stages of free inquiry strategy consist of: lecturers provide orientation questions, students formulate problems, making hypotheses, collecting data to test hypotheses, communicate findings, and draw conclusion. The virtual PCR experiment is integrated in learning free inquiry. The application of PCR laboratory virtual (PCR-virlab) installed on student laptops. At the end of the lesson the lecturer gives a posttest with the same questions at the pretest, and asks students to fill out the questionnaire.

The results of pretest and posttest are scoring by calculating the number of correct answers. Improvement of conceptual mastery is calculated by the n-gain formula (normalized gain) according to [13]. Questionnaire data were analyzed descriptively by percentage to find the trends displayed by
the research subject and confirm the results of quantitative analysis. Questionnaire answers on the "strongly agree" and "agree" scales are interpreted as positive student responses, while questionnaire responses on the scale of "lack of agree" and "disagree" mean negative student responses.

3. Result and Discussion

3.1. Characteristics of the PCR-virlab
The program of PCR-virlab is created with the Adobe Flash CS6 application with action script 3.0. This program consists of simple text, images, simulations, and videos developed with the intention of being an alternative molecular biology experiment activity that cannot be implemented due to limited laboratory facilities. Therefore, this PCR-virlab is designed for students to do experiment even though it is virtually. This virtual PCR experiment can be done if students review the literature on how to do PCR in real works. This means that students not only watch the PCR-virlab program, but doing the PCR experiment step by step like a hands-on laboratory activity. If students do not try to learn PCR techniques from the literature first, then they will not be able to do this virtual PCR experiment. Characteristics of the PCR-virlab program are facilitating student interaction in conducting PCR experiments that are on the computer as if students are doing PCR experiment directly. [14] also developed an interactive virtual chemistry laboratory application, but was not used to assess mastery of concepts.

3.2. Improvement of conceptual mastery
The acquisition of conceptual mastery values can be seen in the following table:

| Aspect      | Pretest | Posttest |
|-------------|---------|----------|
| Lowest value| 19,05   | 23,81    |
| Highest value| 66,67 | 71,43    |
| Average     | 37,77   | 52,38    |
| N-gain      | 0,23 (low category) |

As many as 82.8% of students increased mastery of the concept, meaning that in general the mastery of the concept of students increased individually. But the score of improvement so small that the n-gain value is also small (the criteria are low). The lowest and highest scores at the pretest and posttest also did not differ significantly, but the average of pretest and posttest showed a significant difference based on paired-samples T test obtained sig. value 0.000>0.05, so it was concluded that PCR virlab contribute to mastery of PCR concept. The results of this study are similar to the results of the[15] study which found that the level of concept understanding of the experimental group (\( \bar{x} = 11.30 \)) was statistically higher than the control group (\( \bar{x} = 9.25 \)) with the using of the virlab program of Crocodile Clips Chemistry.Meanwhile, [16] found an online questionnaire filled by students that Western Blotting vLAB was at least equivalent to a real laboratory in the development of student concepts.

3.3. Student responses to the PCR-virlab program
Interpretation of student responses, namely: a) as many as 98% of students thought that learning with virtual PCR practicum was their first experience, while 2% thought that learning like this was often done by other lecturers; b) 96% of students thought that learning with this virtual PCR experiment could motivate them to learn Molecular Biology better, while 4% said they were not interested in learning like this; c) as many as 86% of students thought that learning with virtual PCR experiment was efficient and effective to replace the actual PCR experiment, while 14% thought that this virtual PCR experiment could not replace the actual PCR experiment; d) as many as 93% of students think that the practicum procedures presented in this virtual PCR facilitate them to understand the concept of PCR well because it is concise, clear, interesting, and easy to understand, while 7% of students think that
the practical procedures presented in the virtual PCR are unclear, convoluted, and it looks unattractive, confusing to understanding the concept. Based on the results of the questionnaire data analysis, it can be stated that on average 93% of students gave positive responses to learning with the virtual PCR experiment, and 7% of students gave negative responses.

The implications of using a virtual laboratory in learning are more related to non-cognitive aspects, as [17] in his study concluded that the virtual laboratory has the potential to improve pre-laboratory preparation, and students feel much more confident and comfortable operating laboratory equipment after completing cases which is presented in a virtual laboratory. Overall, the results of this study indicate that the use of PCR-virlab media in free inquiry learning can improve the conceptual mastery of the PCR concept even though the increase score is low. Allegedly students experience difficulties in following free inquiry learning. Further studies are needed to find the causes of the low improvement in conceptual mastery of PCR concept.

4. Conclusion

Based on the data analysis, can be concluded that the PCR-virlab program can be used to improve the conceptual mastery of students' even though the improvement score is low. Most of the students responded positively to the PCR-virlab in the study of molecular biology. Further research can be directed to examine the effectiveness of multiple choice objective test instruments to assess the conceptual mastery in free inquiry learning. In addition, the possibility of misconceptions caused by the use of virtual laboratories should also be a concern for subsequent research.

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