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Design Development Research Approach in Developing Gel Electrophoresis Virtual Laboratory to substitute Real Practicum

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Abstract

One of the purposes of Genetic practicum is that students can understand DNA separation techniques, by conducting gel electrophoresis practicum. Some Institutions of Teacher Training (LPTK) have problems in gel electrophoresis practicum due to unavailability of the lab. For this reason, it is necessary to try a replacement practicum in the form of a virtual laboratory to meet practicum objectives. This research uses a design development research (DDR) approach, through six stages, namely 1) identifying problems by determining indicators of learning and supporting literature studies, 2) determining the purpose, 3) designing and developing devices by designing virtual laboratories, determining the software that will be used, compiling a virtual laboratory storyboard and expert validation, 4) testing, 5) evaluating the results of the trial, and 6) communicating the results of the trial. The validated device was tested on a limited basis on 38 student participants who took genetic practicum. Data on laboratory reports on virtual laboratory gel electrophoresis were analyzed descriptively based on the students' ability to understand gel electrophoresis. 95.89% of students have the ability to understand gel electrophoresis.

1. Introduction

One of the objectives genetic learning is to understand and assess gene expression as eukaryotic cell control in various organisms. The learning objectives are achieved in genetic practicum activities, namely in the gel electrophoresis practicum with the specific aim of understanding and being able to do compound separation techniques. This practicum activity is usually carried out in Teacher Training Institutes (LPTK) that have gel electrophoresis laboratory equipment. What if the laboratory equipment as an important facility is not yet available? In genetic learning, innovation is necessary both in the classroom learning process and in the practicaum activities. Learning activities carried out using learning innovations such as learning media, can enhance students' learning outcome and literacy in science. Science learning through practicum activities effectively develops student competencies such as critical thinking skills (Setia et al., 2013), science process skills (Sen & Sezen Vekli, 2016), generic science skills, creative thinking skills and other high-order thinking skills. The development of student competency as a prospective educator needs mastery of science content (Mthethwa-Kunene et al., 2015) which needs to be done by optimizing laboratory activities. During the process of science learning which involve laboratory activities, the existence of a laboratory is very crucial. Learning activities in the laboratory can develop research skills including observing, using tools, practicing the laboratory activities, reporting experimental results, improving critical thinking skills, analyzing, deepening knowledge, and developing honesty and responsibility, and training students to plan and carry out experiments (Bortnik et al., 2017).

The real practicum activities in the laboratory are better at facilitating laboratory skills for students (Herrani, 2017), but what if in reality the devices that support practicum activities such as gel electrophoresis devices are not yet available in all Teacher Training Institutes? For this reason, it is necessary to develop a virtual laboratory which is a computer-assisted learning media as a solution to simulate practicum activities in the laboratory. Virtual laboratories as one of the innovations in learning can be adopted in schools or Teacher Training Institutes. The use of virtual laboratories greatly helps the learning process in accordance with the learning objectives of Teacher Training Institutes that do not have adequate laboratory facilities, and it can foster scientific attitudes and science process skills to students in finding the concept of compound separation by gel electrophoresis without working in a real laboratory. Virtual laboratories are cheaper, safer and suitable for use by students who have a visual learning style (Herga et al., 2014: 2016). Students can explore their knowledge in a flexible way according to their speed and learning needs.

Virtual laboratories are presented with the help of computers. Computers and technology have impacts on learning. Technology has an important role in our efforts to improve learning outcomes by optimizing its use (Arends, 2008; Ejikeme & Okpala, 2016). Practicum carried out with virtual laboratory media (Adita & Julianto, 2016) becomes more interesting and effective because this media has advantages in several ways including the use of animation techniques combined with flash programs can make abstract concepts concrete so as to increase understanding of the concepts (Athaillah et al., 2017). Virtual lab is also good for students to practice independent learning, familiarize students with critical and creative thinking, attract students' attention and motivation, and can be presented through the internet or files, as an efficient and effective practical simulation tool that involves students directly. With the virtual lab students better understand the concepts so that the objectives of practical activities can be achieved. Teaching involves activities that teach science like a scientist (Chen & Steenhoek, 2014), where students understand how science is found. Students need to be trained in some scientist's skills, namely high curiosity, honesty, objectivity and scientific inquiry and can solve problems scientifically. Genetic learning can be carried out with a variety of approaches to improve students' understanding of the concept of genetics, and it can also improve scientific reasoning abilities for students (Kılıç & Sağlam, 2014).

The use of virtual learning activities in the laboratory by means of simulation using software can improve students' ability in analysis and interpretation, and make them easier to understand genetics. 21st century skills can be grown in students by conducting plant extraction practicum activities that can improve laboratory activities for students (Alozie et al., 2012), so that virtual laboratory activities conducted by students are also the activities that foster 21st century skills. Son (2016) compared student's practicum activities both in virtual and real practicum as well as the combination of virtual and real. It was found that there were significant differences in students' attitudes and learning outcomes between virtual laboratories and real labs, where virtual laboratory activities were better than real laboratory activities . The rapid development of the world in the technology era has made Alozie et al., (2016) recommends that virtual laboratory activities can be adopted in the learning process in the classroom and in the laboratory.

Developing virtual laboratories needs to be done using development designs that are appropriate and in accordance with the development objectives, which is developing tools and models. According to Richey and Klein (2014), the design development that is appropriate in practicality and usefulness is the design development research (DDR) so that the writer considers it necessary to use this development design in developing gel electrophoresis virtual laboratories.

2. Method

The development of Gel Electrophoresis Virtual Lab uses the design development research (DDR) approach, which is a design of product and tool research. The development design research (DDR) is the right choice in developing Gel Electrophoresis Virtual Lab considering its pragmatism in testing the theory and validating the practicality of the results of development. DDR is a way to establish procedures, techniques, and new tools based on analysis of specific needs (Richey and Klein, 2014).

Developing gel electrophoresis virtual lab is a category of development of tools and products. Research on virtual laboratory development was done in six stages: 1) identifying problems by determining learning indicators and supporting literature, 2) determining development goals, 3) designing and developing devices which include: a) make a virtual laboratory design, b) determine the software to be used, c) compile a virtual lab storyboard and d) obtain expert validation, 4) testing the device, 5) evaluating the results of the tested device and 6) communicating the results of the test or trials. The design flow chart of the gel electrophoresis virtual lab and PCR is illustrated in Figure 1 below.

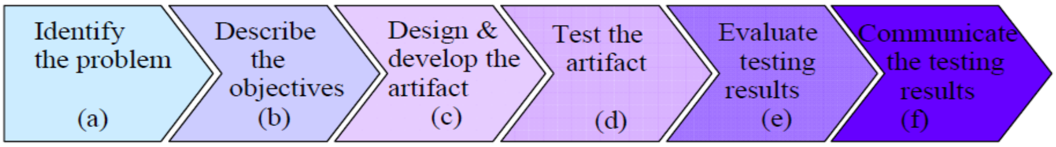

Figure 1. Stages in developing gel electrophoresis virtual lab and PCR
(Sources: Ellis and Levy, 2010)

The development of virtual laboratory devices follows the steps as in Figure 1, then it was tested in a limited number of students to determine the effectiveness of Gel electrophoresis virtual laboratory devices in genetic practicum. In this study virtual laboratory devices were tested on 38 prospective teacher students who had passed genetic course, then improvements were made based on the suggestions and input obtaiend from the limited test. After some improvement, the virtual laboratory device is then re-tested on 5th semester biology students during genetic practicum. The research data is in the form of lab reports with Gel electrophoresis virtual laboratories which are assessed according to the practicum report assessment instrument based on the standard provisions set by the math and science laboratory center. Data on students' ability to understand gel electrophoresis include eight indicators as follows: 1) understanding the purpose of gel electrophoresis, 2) understanding stages of gel electrophoresis practicum activities, 3) understanding stages of DNA isolation, 4) understanding agarose gel making process, 5) understanding how to load isolated DNA into agarose gel, 6) understanding the technique of separating compounds by electrophoresis method, 7) being able to analyze the similarity index of samples from the length of DNA fragments through the results of Polymeration Chain Reaction (PCR), and 8) number of students who gave positive responses that virtual gel electrophoresis devices can help students' understanding on gene expression as eukaryotic cell control in various organisms.

3. Result and Discussion

1. Developing gel electrophoresis virtual lab and PCR

The research design in developing a virtual laboratory of gel electrophoresis was elaborated by the steps in Figure 2.

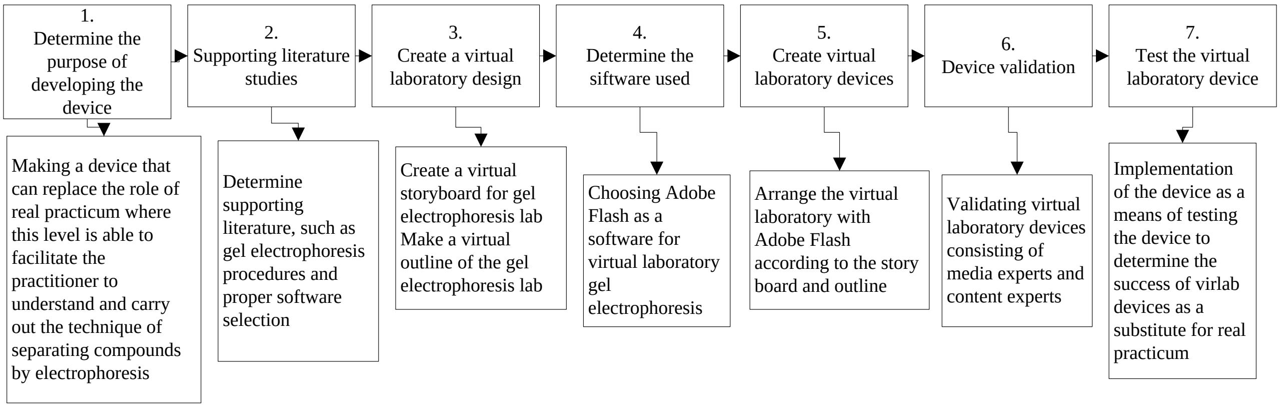

Figure 2. Steps in gel electrophoresis virtual lab development by adopting and modifying that of Ellis and Levy (2010)

Step of developing a virtual gel electrophoresis laboratory are described in figure 1. Stages of development include; 1) Making a device that can replace the role of real practicum where this level is able to facilitate the practitioner to understand and carry out the technique of separating compounds by electrophoresis, 2) Determine supporting literature, such as gel electrophoresis procedures and proper software selection, 3) Create a virtual storyboard for gel electrophoresis lab; Make a virtual outline of the gel electrophoresis lab, 4) Choosing Adobe Flash as a software for virtual laboratory gel electrophoresis, 5) Arrange the virtual laboratory with Adobe Flash according to the story board and outline, 6) Validating virtual laboratory devices consisting of media experts and content experts, and 7) Implementation of the device as a means of testing the device to determine the success of virtual laboratory devices as a substitute for real practicum.

2. Validation of gel electrophoresis virtual lab devices

The process of developing gel electrophoresis virtual laboratory was carried out by accommodating published research data on gel electrophoresis, and the samples used in gel electrophoresis was based on the local potentials, assuming that the samples used were those known by the practicum students. In developing the gel electrophoresis virtual lab we used three samples: mangoes, oranges and bananas, which are local potentials of this region. The three samples of fruit have a considerable varieties in Cirebon and its surrounding areas. Students were expected to be able to understand the causes of differences between the varieties of each sample. The results of the three samples come from published secondary data so that the results of the three samples are accurate and valid.

The gel electrophoresis virtual laboratory device that has been developed is then validated by expert validators which includes expert validators in media and genetic content. Validation data of gel electrophoresis virtual laboratory devices are shown in Table 1.

Table 1. Validation results on gel electrophoresis virtual laboratory devices

Validator	Feasibility Indicator	Expert Judgement
Media	In line with the revision	Can be tested on limited basis
Genetic content	In line with the revision	Can be tested on limited basis

Validation results stated that gel electrophoresis devices are in accordance with several feasibility indicators. The display of gel electrophoresis virtual laboratory devices uses adobe flash software because it is easily applied as a learning media and is interactive so that it is easy for students to understand. Some displays of virtual gel electrophoresis laboratory devices using adobe flash software are shown in Figure 3.

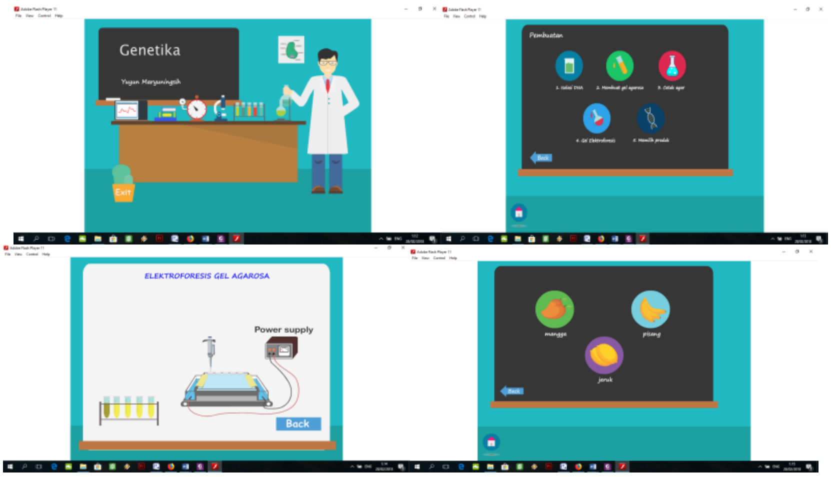

Figure 3. Several displays of the gel electrophoresis virtual laboratory

3. Testing the gel electrophoresis virtual laboratory device

The virtual laboratory gel for electrophoresis device was then tested on a limited basis on 104 third-year students taking genetic course. The practicum activity report is assessed based on the student's ability in making the electrophoresis virtual lab report as outlined in Table 2.

Table 2. The percentage of students' mastery based on the stages of gel electrophoresis and PCR

No	Student ability in virtual lab reports	Student's percentage (%)
1	Understand the purpose of gel electrophoresis	97,26
2	Understand the stages of electrophoresis gel practicum activities	93,15
3	Understand the stages of the DNA isolation process	95,89
4	Understand the process of making agarose gel	93,15

No	Student ability in virtual lab reports	Student’s percentage (%)
5	Understand how to insert isolated DNA into agarose gel	89,04
6	Understand the technique of separating compounds by electrophoresis method	93,15
7	Able to analyze the similarity index of samples from the length of DNA fragments	86,30
8	Virtual gel electrophoresis can help students understand gene expression as eukaryotic cell control in various organisms	95,89

The data on the results of the virtual laboratory practicum on gel electroctraphoresis showed that 95.89% of students had the ability to understand gel electrophoresis. This shows that the electrophoresis virtual device that has been developed can help students 1) understand the purpose of gel electrophoresis, 2) understand the stages of electrophoresis gel practicum activities, 3) understand the stages of DNA isolation, 4) understand the process of making agarose gel, 5) understand how to load isolated DNA into agarose gel, 6) understand the technique of separating compounds by electrophoresis method, 7) be able to analyze the similarity index of samples from DNA fragment lengths and 8) achieve the learning objectives, namely understanding gene expression as eukaryotic cell control in various organisms. Virtual gel electrophoresis that has been developed by the writer can be used in the learning process and laboratory activities.

The use of Design Development Research (DDR) in the development of virtual gel electrophoresis using the adobe flash software application is appropriate considering that developing virtual laboratories is the development of tools and products whose development includes determining learning indicators, supporting literature studies, designing virtual laboratories, determining the software used, compiling laboratory equipment, device validation and device testing in a limited and broad manner. Table 2 shows that the average percentage of the electrophoresis lab report obtained by the practicum students is above 85 for each indicator, meaning that the virtual electrophoresis laboratory that has been developed can be used as a substitute for real laboratory.

In this study there are still weaknesses, where the electrophoresis data is secondary data obtained from published scientific articles, therefore it is necessary to re-develop and improve it by using primary data obtained by researchers personally by conducting gel electrophoresis in real lab practice . Virtual laboratory development is essentially developing a learning device in the form of product software with the aim of enabling students to understand gene expression as a control of eukaryotic cells in various organisms, with indicators that that include understanding the technique of separating compounds by electrophoresis and being able to analyze similarity indexes of DNA fragments. This study is in accordance with Cunningham et al., (2006) that the purpose of designing this device includes four objectives: 1) to introduce DNA gel electrophoresis, in a fun, inquiry-based manner to students; 2) to encourage students to think critically, 3) to show students how an experiment can be optimized from the beginning of an uncertain point; and 4) to convey practically the basic knowledge needed to conduct DNA electrophoresis and discuss it.

The research results obtained by the author is in line with the opinion that virtual learning (Aubrie & O'Donnell, 2009; Ketelhut & Nelson, 2010; Muhamad et al, 2010; Nirvana, 2011; Totiana, 2012; Fitriyana et al., 2013; Hamida et al., 2013; Argandi et al., 2013; Setia. 2013; Simbolon. 2015; Gunawan et al., 2017; Jacobson et al., 2016; Prabowo et al., 2016; Adi et al., 2016; Kusdiastuti et al., 2017; Pambudi et al., 2015; Bortnik et al., 2017) is a learning that can be done for abstract concepts, such as those chosen by the author i.e. Gel electrophoresis which is a derivative of the main concept of regulation of gene expression. This research was conducted first by developing a virtual laboratory device in accordance with the learning objectives i.e. to be able to facilitate the students in carrying out laboratory activities (Alozie et al., 2012; Ceylan & Sezen Vekli. 2016; Herrani, 2017) as the students can work and think like scientists do (Chen & Steenhoek, 2014). The gel electrophoresis virtual laboratory program that has been developed by the writer is in line with electrophoresis that was developed by Cunningham et al., (2006), so that the virtual gel electrophoresis devices that have been developed are feasible to be applied in genetic learning and practicum such as virtual practicum on science education suggested by Alozie et al., (2016).

In line with the development of research on molecular genetics, further development of the gel electrophoresis virtual laboratory equipment is needed to suit the development of molecular genetics and it is hoped that the use of primary data obtained from gel electrophoresis in real practice in the laboratory and embedded in the data from virtual laboratory devices on gel electrophoresis with the use of diverse plant samples. The use of DDR according to Richey and Klein (2014) is appropriate and can be used in research on the development of tools and models, considering that DDR is a development design that is appropriate in its practicality and usefulness. DDR (Richey & Klein, 2014), is also appropriate to be used for other development studies, such as the development of learning media or devices both in software and application, given the DDR stages which include six stages adapted to development, namely 1) identify problems, 2) determine and compile development objectives, 3) design and develop tools, 4) test or try the device, 5) evaluate the results of the trial and 6) communicate the results of the trial.

4. Conclusion

Design development research (DDR) is a research design used to develop tools and products. The gel electrophoresis virtual laboratory is a software-based application that enables students to understand gene expression as a control on eukaryotic cells in various organisms, with indicators that they understand the separation techniques of compounds by electrophoresis method and are able to analyze similarity indexes of DNA fragments. Gel electrophoresis Virtual Laboratory that have been developed can be used as a substitute for real labs. And this virtual labs can increase the average score of student lab reports so that students fully understand DNA separation techniques and measurement of DNA fragments just like real labs in research laboratories. From the research results, the writer recommends wide use of gel electrophoresis virtual lab in some Teacher Training Institues that do not have complete scientific laboratory equipment due to limited equipment or procurement costs. This study needs to be improved by conducting research that measures the length of DNA fragments using polymerase chain reaction (PCR) from several test plant samples, then the research data which is primary data is used as data in the length testing of DNA fragments in virtual gel electrophoresis and PCR.

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