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Original Research Article

The Development of Problem Based Virtual Laboratory Media to Improve Science Process Skills of Students in Biology

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ABSTRACT

This research was conducted to find out:1) the feasibility level of problem based virtual laboratory media of ecosystem sub topic (biogeochemical cycle) according to material experts media design experts, instructional media experts, virtual technology experts, 2) the feasibility level of media according to students and teachers responses, 3) to know the improvement of student's science process skills after using problem based virtual laboratory media of biogeochemical cycle in learning process in senior high school. Based on the results of the validation of material experts, media design experts, instructional design experts and virtual technology experts the results were very good, the percentage values were 95% 85.5%, 85%, 90.62% respectively. Student's responses on media from individual trial, small group trial and limited group trial showed that virtual media developed was also very good, with average scores 91%, 90.25%, 92%, respectively. Teacher's responses on media from individual trial, small group trial and limited group trial were very good too with average scores 79%, 92%, 91%, respectively. In conclusion, the media developed was considered very good and feasible to use as learning media. Effectiveness of media was found out by carrying out pseudo-quasi experiment on first grade students in senior high school SMAN 1 Lubuk Pakam. Two classes were taken by *cluster random sampling* method as sample, X MIPA 1 as experiment class and X MIPA 4 as control class. Research result showed that student's science process skills score that be thought by problem based virtual laboratory media was significantly higher or better than class without virtual laboratory media (t_{count} = (3.62) > t_{table} = (1.67) at $\alpha = 0.05$).

Key words: *Virtual laboratory, science process skills*

1. INTRODUCTION

Technology information development in recent years has developed at tremendous speed, it has changed society paradigm in finding and obtaining information, which is no longer limited to newspaper information, audio visual and electronic, but also other information sources such as by internet network (Husaini, 2014). Fojtik (2015) and Husaini (2014) argued that the use of information technology in the field of education has an important meaning, especially in efforts to equalize educational opportunities, improve the quality of education. According to PISA survey in 2015, there was a significant increase in educational achievement in Indonesia, which about 22.1 points. These results put Indonesia in fourth place in terms of increasing student achievement compared to the results of previous surveys in 2012, out of 72 countries participated. Nevertheless, based on the time of science learning, 4% of Indonesia's students were recorded not at all required to take science subjects, this is inversely proportional with other OECD countries, which 94% of their students take one science subject in a week. The inability to follow science subjects is five percent greater in disadvantaged schools, compared to more advanced schools. Meanwhile, advanced schools in Indonesia offer more science learning group activities than disadvantaged schools. Only 29% students from disadvantaged schools given the opportunity to take part in science study groups, while 75% of students in advanced schools have more opportunities (Kemdikbud, 2016).The application of active problem-based learning is a learning model that has a positive influence on student's academic performance and their attitudes towards science subjects. It was also found that the application of problem-based active learning models positively influenced student's conceptual development and made their misunderstandings at the lowest level (Akinoglu & Tandogan, 2006). According to Muhamad *et al* (2012), virtual technology generally as well as the Scenario Based Learning approach in particular, when integrated into systems to improve teaching and learning, have proven to be promising tools to help students gain knowledge in science. According to Sunarno (2009), one of the innovative products of computer-based learning media and technology can be applied in schools that have implemented information technology (IT) in the learning process is the use of virtual laboratories. This new innovative product can create the students to have a scientific attitude in finding concepts without working in a real laboratory. Practicing in a real laboratory cause students must face with several obstacles such as safety, time and costs (Breakey *et al*, 2008; Muhammad *et al*, 2012, Scheckler, 2003; Tuysuz, 2010; Yeni &Yokhebed, 2015; Yuniarti *et al* , 2012).

Problem Based Learning (PBL) is an approach that stimulates students to learn through involvement in real problems. Therefore, an important element of PBL works with real-world issues, collaborating with colleagues, and focus on critical questions that frame those issues (Bidokhta & Assareh, 2011). Besides learning methods, internal factors that exist in students must also be considered to gain success of biology learning, such as student's thinking skills, learning motivation, learning styles, student skills, student attitudes, and others. Problem based learning (PBL) as one of the learning models has a characteristic that is always started and centered on problems. In PBL, students can work in small groups and must identify what they know and what they do not know and must have the ability to solve a problem (Fatimah *et al*, 2013). Problem based learning can also explore critical thinking skills and problem solving skills, as well as to acquire essential knowledge and concepts from subject matter and train high-level thinking (Kusumaningtias *et al*, 2013). According to Rusnayati & Prima (2011) efforts to develop students process skills can be done by conducting a learning process in which there are some activities and problem-oriented.

This research was conducted to find out:1) the feasibility level of problem based virtual laboratory media of ecosystem sub topic (biogeochemical cycle) according to material experts media design experts, instructional media experts, virtual technology experts, 2) the feasibility level of media according to students and teachers responses, 3) the improvement of student's science process skills inbiology after using problem based virtual laboratory media that has been developed at topic biogeochemical cycle in senior high school SMAN 1 Lubuk Pakam.

Virtual laboratory in learning process

Virtual laboratories can be defined as a series of computer programs that can visualize abstract or complex phenomena carried out in real laboratory, therefore it can improve learning activities, in an effort to develop the science process skills needed in problem solving. Integrating ICT in learning is a 21st century learning component that can improve inventive thinking skills, effective communication, high productivity, and spirituality (Hiong & Osman, 2013). According to Liem *et al* (2010), Virtual laboratories are simulations or experiments conducted on computers to present natural phenomena that have an important role in science learning process such as physics, chemistry and biology. In other words, Virtual Laboratory is an imitation form of a real laboratory used in learning activities or scientific research to emphasize a concept or explore concepts (Widhy, 2012).

Advantage of Virtual laboratory

According to Lerianti *et al* (2015), Torres *et al*. (2015), Jorda (2013), Afanasyev *et al* (2013), Scheckler (2003) and Dobrzanki & Honysz (2010), the advantages of virtual laboratories are: 1) unnecessary of laboratory equipment and materials, which is expensive, so that it can be an alternative to overcome the limitations or absence of laboratory equipment and materials, 2) Reduce time constraints, if there is not enough time to teach in the laboratory, 3) The ability of computers to display information needed by the user (computer patience) can help slow learner students, 4) More interactive, therefore students can do same physic laboratory practicum in visually more attractive laboratory, 4) Students can held experiment individually or in groups and not obligated to do it in laboratory room, 5) Improve safety and security, because they do not interact with real tools and chemicals, 6) Virtual laboratories can support the ability to experiment with too dangerous things, too global, or the one which takes to much time.

Virtual laboratory in biology learning

Virtual laboratories are considered as new teaching strategies that are cheaper, easier and can attract student's attention in the learning process. Some biology teachers were reported use ICT in the laboratory, which is recognized as the basis of science teaching (Špernjak & Šorgo, 2010). The obstacle faced by teachers when dealing with conducting experiments in their teaching is usually about the subject. This is includes a lack of chemical solutions supply and the damage to laboratory equipment. Therefore, laboratory assistants or technicians need to be called and it will take a time (Muhamad *et al*, 2012). If facilities are not available, in many cases, a student might be an audience in conducting experiments. Students are not free to experiment according to their own schedule, because the time for experiments may be limited to regular learning hours (Tiwari & Singh, 2011)

Topic and Sub topic for development of problem based virtual laboratory

Preliminary analysis was held first to establish the focus topic for developing content for the Scenario-based learning approach for Problem-Based Virtual Biology Laboratory (Vlab-Bio) Preliminary analysis showed that all eight teachers who were given questionnaire, agreed that time, security and costs were obstacles in doing lab work in the laboratory. For example, the lack of facilities and infrastructure to support security in real laboratories, practicum and preparing the student has taken a lot of time. The cost of purchasing expensive equipment and chemicals for testing in labs was often used up and the price was expensive.

In regarding to these obstacles, several topics in biology where practices play an important role have never been done in school, in this case it is necessary to have teaching aid in accordance with technology developments to facilitates practical activities. There are several biology topics that are still abstract and can utilize virtual laboratories in their learning. In the ecosystem topics, there is one sub topic still difficult to explain by the teacher in class. The results of observations at Senior High School 1 Lubuk Pakam showed out of six teachers, all stated that biogeochemical topic was the most difficult topic to explain. Likewise, when questionnaire was given to 35 students in the same grade level, 29 students considered biogeochemical topic as a difficult and very difficult topic and only six students felt it was very easy to learn.

2. RESEARCH METHOD

This research was designed as a Research and Development (R & D) research, which its steps adapted from Borg & Gall (2003). The ten steps of Borg & Gall were grouped based on the research mechanism by researchers into three steps in accordance with the needs of developing a virtual laboratory based on problem solving. The three steps were☹1) Preparation, including needs analysis carried out by analyzing problems found in the field, especially in Ecosystem subjects. (2) Development steps, begins with the preparation of materials regarding biogeochemical cycles, preparation of graphic files, writing scripts for problem-based virtual laboratory scenarios. (3) Product testing, which steps were product validation, product revision and product testing. The product developed in this study is a problem based virtual laboratory about biogeochemical cycles. The data was collected by questionnaire. Six types of questionnaires were used to collect information. The media was validated through several experts (material experts, media design experts, instructional media experts, virtual technology experts), biology teachers and students. Data collected was about the condition of problem based virtual laboratory. The next step was field trials, consisted of individual trials (two teachers and three students), small group trials (four teachers and 10 students), limited group trials (seven teachers and 30 students). Products then be tested for its effectiveness. Effectiveness test of media was carried out in SMAN 1 Lubuk Pakam in the even semester of 2017/2018 academic year. Quasi experiment design (one-group pretest-posttest design) was held in school to find out the effectiveness of media. In this case there were control class and experimental class. Effectiveness test is to see the improvement of science process skills in eight aspects including Observe, interpret, predict, use tools and materials, apply concepts, plan research, communicate, ask questions

3. RESULTS AND DISCUSSION

3.1. RESULTS

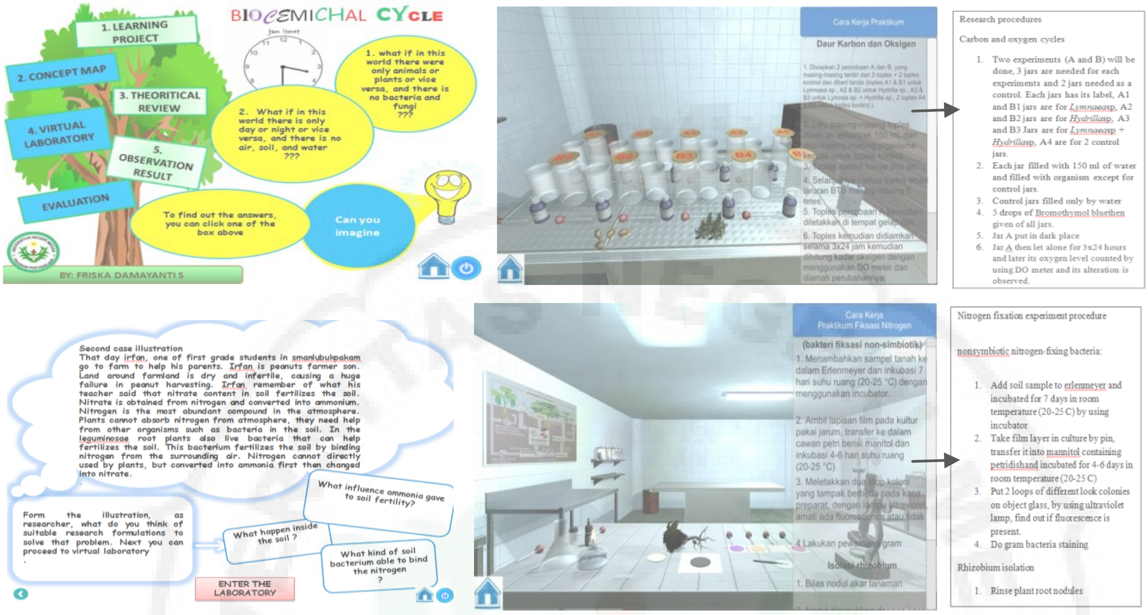
3.1.1. Feasibility of virtual laboratory

The problem based virtual laboratory was developed using Unity application and 3D based. The media not only contain experiment, but also equipped with material and instructions. Below is a scene display in a virtual problem-based laboratory:

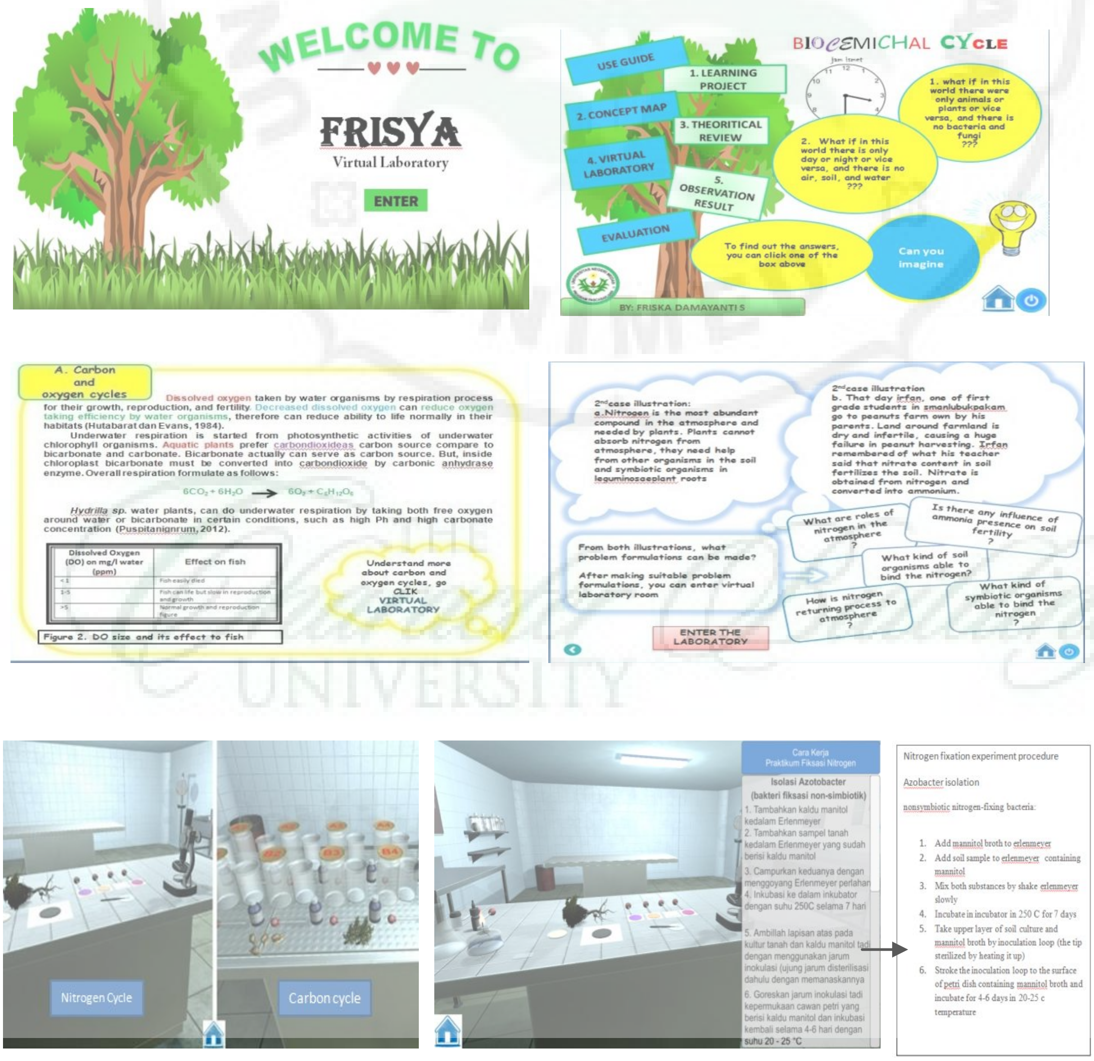
No.	Scene Name	Description
1	Start Scene	Displays the start display for the program, the material, the introduction to the virtual laboratory, until the evaluation with self design 2D GUI (*Graphical User Interface*)
2	1st worksheet test	Display virtual laboratories for carbon and oxygen cycles. This scene limited until the closure of tube A1-A5.
3	1st worksheet result	Displays a virtual laboratory that starts from the state of A1-A5 tube in closed condition. In this scene the user can observe the results of previous lab experiment
4	2nd worksheet,tools and materials fixations	Displays a virtual laboratory to select nitrification lab tools and materials.
5	2nd worksheet,how to do fixation	Displays an animated virtual laboratory when right objects clicked on by the user. After the user finished, the user can proceed to the ammonification lab
6	2nd worksheet,tools and materials ammonifications	Displays a virtual laboratory for selecting ammonification lab tools and materials
7	2nd worksheet,how to do ammonification	Displays an animated virtual laboratory when right objects clicked on by the user. In this scene, users coud also return to the Start Scene to fill in the results and evaluation sheets.

Examples of scenes in problem in virtual laboratory are displayed below

a. Before revision



b. After revision



Problem in virtual laboratory of biochemical cycles topic validation result material experts displayed in Table 1.

Tabel 1. Assessment by content expert

Aspects	Average score	Feasibility
Material	96.25%	Very good
Learning delivery system	91.60%	Very good
Learning strategy quality	93.75%	Very good
Learning support tools	100%	Very good
Material accuracy	95.83%	Very good
Total average score	96.00 %	Very good

Total average score from two experts in material was 95%. The score indicated the media was in "very good" categories. This means the media developed was feasible to use. Also, every aspects of material assessment scored above 90% or chategorized very good.

The validation results of problem based virtual laboratory of biochemical cycles topics from media design experts displayed in Figure 1.

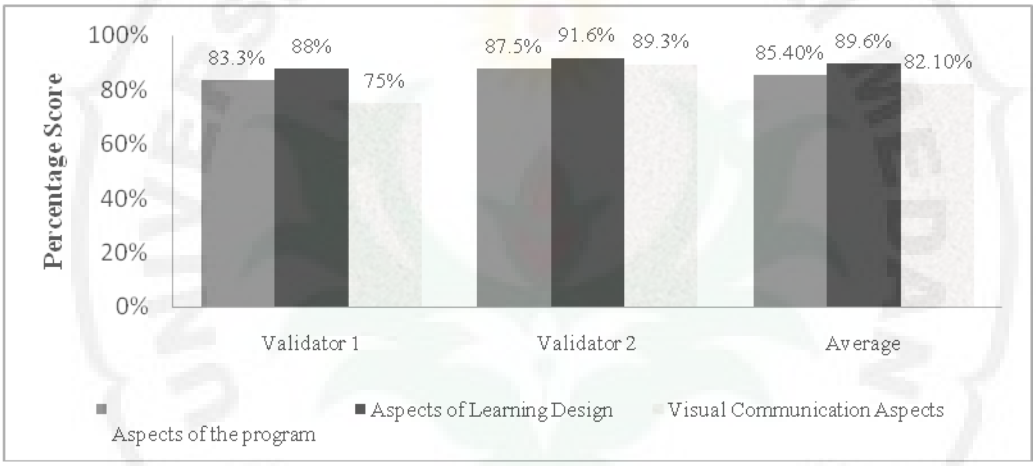


Figure 1. Assessment result of media design expert

Assessment average score from two experts in media design was 85.5%. The score indicated that the media was in "very good" categories. This mean that the media developed was feasible to use according to its design quality. Furthermore, every aspects of design assessment looking from its percentage scores were considered "very good", or in the other words every aspects of its design was feasible to use.

The validation results of Problem based virtual laboratory of biochemical cycles topics from instructional media experts displayed in Figure 2.

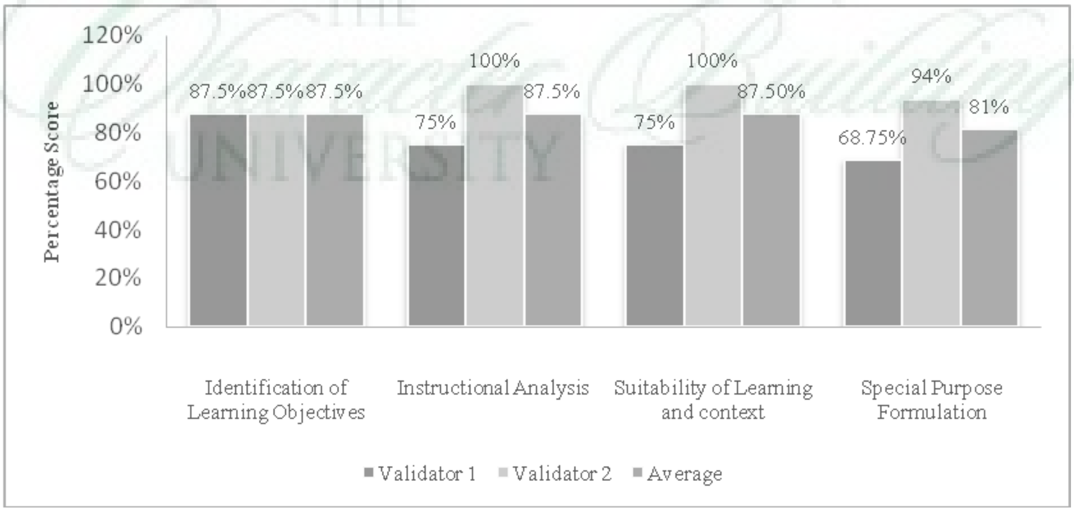


Figure 2: Assessment result of instructional media experts

Assessment average score from two experts in instructional media was 85.5%. The score indicated that the media was in "very good" categories. This mean that the media developed was feasible to use according to its instructional media quality. Furthermore, every aspects of instructional media assessment looking from its percentage scores was considered "very good", or in the other words every aspects of it was feasible to use.

The validation results of Problem based virtual laboratory of biochemical cycles topics from virtual technology experts displayed in Figure 3.

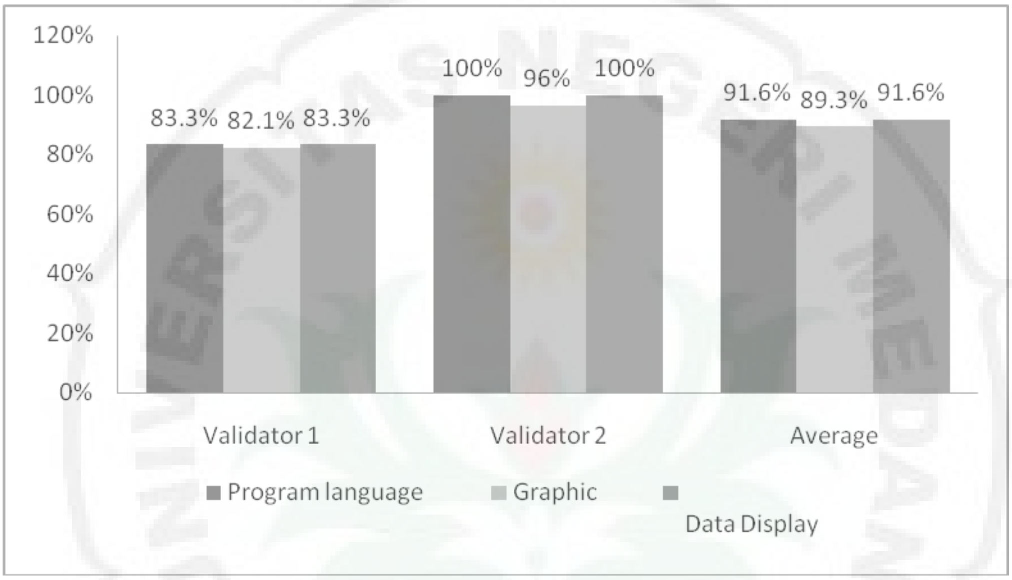


Figure 3. Assessment result of virtual technology experts

Assessment average score from two experts in virtual technology was 90.62%. The score indicated that the media was in "very good" categories. This mean that the media developed was feasible to use according to its virtual technology quality. Furthermore, every aspects of virtual technology aspects looking from its percentage scores was considered "very good", or in the other words every aspects of it was feasible to use.
After this virtual laboratory media validated and revised, the next step was individual trial, small group trial, and limited group trial, all were performed by teachers and students. The results of these trials displayed in Table 2

Table 2. Teachers assessment on virtual media in individual trial, small group trial, and limited group trial.

Aspects	Average (%)		
	individual trial	small group trial	limited group trial
Material quality	83.00	94.00	92.00
Application	81.25	90.00	94.00
Interaction	75.00	94.00	95.83
Design	81.25	91.00	92.01
Evaluations	75.00	91.00	84.20
Total average scores (%)	79.10	91.40	91.61
Feasibility	Very good	Very good	Very good

All trials (individual trial, small group trial, and limited group trial) performed on teachers results concluded the virtual media developed was very good and declared feasible. There are some aspects from individual trial that categorized as good, which were aspects of evaluation and interaction (75%) but still considered feasible.

Furthermore, the percentage results of individual trial, small group trial, and limited group trial were displayed in Table 3

Table 3. Student assessment on virtual media in individual trial, small group trial, and limited group trial

Aspects	Average (%)		
	individual trial	small group trial	limited group trial
Material quality	83.00	88.33	92.00
Application	94.00	95.00	94.00
Interaction	95.83	91.25	95.83
Design	88.88	94.16	92.91
Evaluations	91.67	82.50	84.20
Total average scores (%)	90.67	90.25	91.79
Feasibility	Very good	Very good	Very good

All trials (individual trial, small group trial, and limited group trial) performed on students concluded that virtual media developed was in very good category and declared feasible.

3.1.2. Result of Implementation of problem based virtual laboratory on science process skills

The pretest of science process skills was given to students before treatment to determine the basic score science process skills of both classes. The average score of control class was 31.41 and the standard deviation was 3.95. While the average score of experimental class was 31.05 and the standard deviation was 4.65. The results of the pretest science process skills in the two classes which calculated using t test showed that the two classes did not have a significant difference, so the two classes then suitable as objects in this study ($t_{count} = 0.35 < t_{table} = 1.67$ at $\alpha = 0.05$).

Posttest data of science process skills were obtained after both classes were taught using different learning media. The graph of this posttest result was presented in Figure 4. Based on that test, the average score of control class was 75.53 with a standard deviation of 7.91, meanwhile the average score of experimental class was 82.38 with a standard deviation of 7.80. By hypothesis testing, this difference was significant ($t_{count} = 3.62 > t_{table} = 1.67$ at $\alpha = 0.05$). Therefore, the implementation of problem based virtual laboratory learning media in biology learning proses significantly can improve the science process skills of the student in senior high school.

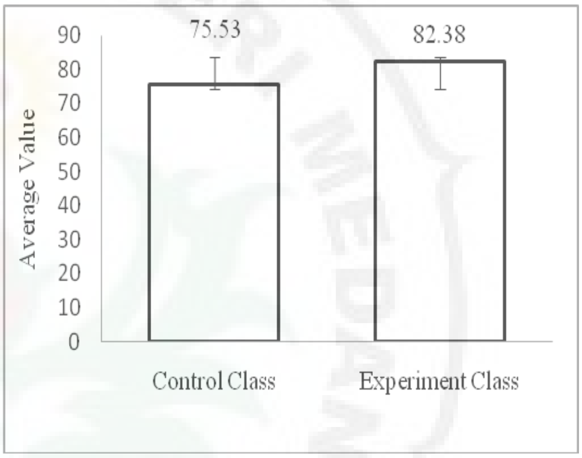


Figure 4. Student's post test results on science process skills

4. DISCUSSION

The virtual laboratory developed was validated by a team of material experts, media design, instructional media, and virtual technology to find out the feasibility of the media. Furthermore, the validated problem-based virtual laboratory then later would be assessed by biology teachers and students. The media were assessed based on several indicators. Each indicator was categorized as very good and considered feasible, although two indicators categorized as "good" (evaluation and interaction) on teacher's individual trial. The assessment result from each expert, teacher and student was very good and the assessment result of the product was high. However, the media still have to through many revisions and suggestions for its improvement. Several revisions include multiple interpretive languages, learning objectives, changing the sentences at the opening (home) of virtual laboratories, alteration in the virtual laboratory of nitrogen cycle material, and alteration in nitrogen cycle work steps. Revision from media design expert team, include the usage guide of the *home* button, and the addition of markers on each box or writing button that could be clicked on. Suggestion from virtual technology experts was to have made good use of space.

Virtual labs that have been developed are feasible to use based on the results of evaluations from several experts namely material experts, media design, instructional media and virtual technology as well as assessments from students and teachers. The material in this virtual laboratory is about the biogeochemical cycle which in this case is abstract material and requires good understanding to master it and the need for this material to help users enter virtual laboratory experiments. The material in this virtual laboratory is presented with an interactive and easily understood delivery system and uses moving animation. Jaya (2015) stated that virtual laboratories can support practicum activities in the laboratory that are interactive, dynamic, animative, and have a virtual environment so it is not boring. This was also confirmed by Pradini *et al* (2015) that stated that students felt helped in understanding the material concepts using the interactive animation media. The design in this virtual laboratory also uses attractive colors and motivates students to learn and the technology used in this virtual laboratory already uses a 3D application program, which helps students to learn it as if it were in the real world. This is revealed by Muhamad *et al* (2012) who stated that VLab-Bio provides a virtual learning environment with real graphics to students and photos to help them see the real tools and chemicals used in the learning process of biology. This was also revealed by Liu *et al* (2015) who stated that the students can obtain information on lab content well from two types of laboratories: virtual and physical laboratories. There is great potential in implementing 3D virtual lab-based games to support teaching and learning in science. In addition, it is important to find practical ways to design and develop intelligent systems based on 3D games with limited forms of complexity. 3D virtual environments provide immersion into the content of learning, and interaction in the virtual world of games, which is governed by established scientific principles. This virtual laboratory created a new experience for students and teachers, because by using this virtual laboratory students can use it independently and do learning outside of school hours and teachers can also save time to teach biogeochemical cycles that are abstract in nature. The use of tools and materials in the laboratory will also be more efficient. This is also expressed by Torres *et al* (2015). During the activity time, the student can interact with laboratory instruments. Even when following instructions, the student may overlook some details, which could lead to accidents or laboratory instruments damage. The research includes an analysis of the construction of a virtual lab and experience of users throughout their educational experience.

According to the results of this research that showed the effect of using laboratory-based problem solving on science process skills students at SMAN 1 Lubuk Pakam, it can be concluded that the teaching material of biogeochemical cycle ecosystems using virtual laboratory-based problem solving have a positive impact on science process skill test scores in Biology SMA N 1 Lubuk Pakam. The results of this research are consistent with those from several other studies about the effectiveness of virtual laboratory using in learning process on science process skills. Jaya (2015) and Liu, *et al*. (2015) for example have stated that 3D virtual laboratories can help students better in understanding of the science process and also improve more science process skills well. In addition, a virtual laboratory based on problem solving in the sub-material ecosystem also provides learning experiences that can lead to increase student science process skills. In this case such as problem formulation, introduction of practicum tools, practicum work procedures/steps and making observations. Besides that, virtual laboratory can cause students to carry out some science activities, such as interpreting, predicting, applying concepts, planning research, communicating results and asking questions. Harahap *et al* (2019) furthermore added that the availability of virtual assignments, students were asked more active to carry out scientific activities such as interpretation, prediction, hypotheses formulation, questions asking, concept applying, research planning, and communicating the results of research. Therefore, with so many learning aids and scientific discussions between students and lecturers, students are able to improve their science process skills. Flowers (2011) also said that students prefer to participate in virtual labs compared to traditional (e.g., face-to-face) labs. Data also indicated that students perceived higher learning gains as a result of participating in virtual labs compared to traditional hands-on labs.

5. CONCLUSION

Based on the research results and hypotheses testing, it can be concluded that problem-based virtual laboratory media of ecosystem subtopic biogeochemical cycles that has been developed has a very good quality according to material experts, media design experts, instructional design and virtual technology experts. According to teacher and students responses, individual trial, small group trial and limited group trial, the virtual laboratory media that has been developed also has very good quality. The using of a virtual laboratory that has been developed in biology learning process can improve student's science process skills.

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