Students' Problem-Solving Skill in Physics Teaching with Virtual Labs

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ABSTRACT

Problem-solving is a high-level ability to find solution to a problem. In the problem-solving process, students have to identify and understand the problems, plan the solutions, execute the plans and review the resolution process. This ability is needed by students to produce meaningful knowledge. This article discusses the effect of virtual labs in physics learning toward student's problem-solving abilities. The improvement of problem-solving skills was analyzed in each step of the solution process. This quasi-experimental study was conducted at three different senior high schools. There were 165 students participating in this study, all of whom were divided into three experimental groups and three control groups. The research instrument used was five to eight questions of essay test. The results showed that the problem-solving ability of the experimental group was higher than that of the control group at each school. The analysis of each problem-solving step showed that, in each school, the students' ability to identify and define the problem and also to establish goals and objectives show a similar result. Students have an excellent ability in identifying problem up to plan for problem-solving, whereas for the step of analyzing the choice of ideas and step to follow up of problem-solving overall still need to be improved. Students who are unable to complete a particular problem-solving step will not be able to complete the next step well.

Keywords: problem-solving skill; physics teaching; virtual labs

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INTRODUCTION

Science is a collection of knowledge that seeks to explain every phenomenon that occurs in nature. Through the phenomenon of science, learners can exercise the ability to observe, analyze, hypothesize, predict, string, measure, and draw a conclusion (Bulan et al., 2015). The challenge in science learning does not only require learners to master the concept, but also to develop their thinking skill. One of the high-level thinking skills that learners must develop is a problem-solving skill. Learners can possess this ability after being able to understand the material and concept of physics well, precisely, and directed.

A good understanding of the concept of physics can be a reference for students to solve various problems that exist on the subject of physics. The problem that students often encounter is the difficulty in interpreting concrete and abstract concepts of physics. Students become unable to track the right solution to solve the problem. Also, the physics issues presented today contain high-level thinking skills. Students then have difficulty in identifying, understanding, identifying, and analyzing the physical difficulties they face.

The ability to identify and analyze concept is necessary to solve a physics problem. When working on physics questions, learners often use mathematical equation without first analyzing the problem, such as guessing the formula used or memorizing examples they've already used to work on other questions. They accidentally go straight to the stage of analyzing the problem. This will result in the incorrect use of physics concept because the root of the problems is not identified first. On the other hand, teachers often prioritize the delivery of materials directly without providing opportunities for learners to participate in analyzing the ways or process of solving an existing problem. One of the right solutions to overcome this condition is to improve students' problem-solving skill by changing learning methods with learning activities that support the development of those abilities.

Problem-solving is the prototype of an activity that depends on the controlled process. Controlling process allows one to face a new situation where automatic production procedures and production have not been studied. Otherwise, the situation will not be a problem (Goldhammer et al., 2014). Problem-solving skill is one form of high-order thinking skill. Buteler & Coleoni (2016) states that problem-solving is an activity that teachers choose to help students learn about the concept. At the same time, the success of problem-solving is widely regarded as an excellent indicator of the success of understanding the concept being learned. This problem-solving behavior is closely related to one's characteristics. While solving many problems does not guarantee that students will achieve the desired conceptual development, physicists do achieve much of their conceptual understanding by answering a large number of problems. People who have good problem-solving skill can have a better life than others because they are more successful in finding the best solution and knowing how to behave in a problematic situation (Coşkun et al., 2014).

Students' problem-solving skills can be developed through innovations in physics learning. One of them is through the utilization of information and communication technology. According to Gunawan et al. (2017d), the more interesting media used during the learning process, the faster the transfer of knowledge to learners to enhance the understanding of learners. Learning media such as computer simulations and animations can be presented effectively to teach and visualize the concept of abstract or difficult science. Tüysüz (2010) stated that the benefit of information technology in laboratory activities that to increase students' learning interests so that learning outcomes will also increase. Tsovaltzi et al., (2010) revealed that laboratories developed through information technology or are known as virtual labs provide many of the physical items found in real laboratories. Students can do the activity of drag and drop tools and practicum materials just as easy as clicking on the menu options available, which can be compiled for specific problems. Therefore, the virtual lab allows students to experiment on their own independently, without having to follow instructions. The use of virtual laboratories in learning also makes it easier for students to perform experimental activities oriented toward microscopic representation, which is impossible to do in real laboratories (Ko et al., 2001). In the event of student experiment failure, the virtual laboratory will not cause any real damage (Chen et al., 2010). About study-time allocation, Muhamad et al. (2010) state that virtual labs are considered convenient and flexible. The use of virtual laboratories allows students to experiment safely, fun, and students gain practicum experience without actually putting them on potentially harmful lab materials.

The use of virtual laboratories provides an opportunity for students to get acquainted with new strategies in learning that support high-level skills such as communication and information literacy, self-management skill knowledge, problem-solving, self-study, cooperative learning and the like (Herga & Dinevski, 2012). Gunawan et al. (2017b) also reported that the use of virtual laboratories is one of the alternative learning strategies with the limitations of experimental tools that can develop student creativity. This study investigates the effect of the virtual physics lab on the students' problem-solving abilities in three different schools. Obtaining students' problem-solving skill scores are then reviewed based on five steps of problem-solving skills namely, identify and define problems, define goals and objectives, generate solutions, make a plan of action, and follow through. The five problem-solving steps in this study follow the troubleshooting steps proposed by Ferguson (2004).

METHOD

In this research, we have developed a virtual laboratory on several concepts of physics. The testing phase used the quasi-experimental method to examine the effectiveness of the virtual laboratories in the problem-solving skills of students. This quasi-experimental study used a pretest-posttest control group design performed on three different high schools. The selection of more than one school was based on the consideration of obtaining more comprehensive data on different school characteristics. The purposive sampling technique chose the samples, and the total number of participants were 165 students divided into 3 experimental groups and 3 control groups. The research instrument was used a type of problem-solving test, is an essay question which consists of 5 to 8 items. The experimental group was given treatment in the way of laboratory use of virtual learning, while in the control group was given treatment in the way of traditional learning. Students' problem-solving abilities in each sample group at the three schools were compared.

The problem-solving capability of data obtained is also based on the scores gained for each troubleshooting step. The scores of increasing problem-solving abilities in each school have been grouped into three categories, namely high ($x > 70$), medium ($30 \leq x \leq 70$), and low ($x < 30$). The same categorization is also carried out on improving the ability at each problem-solving step (Gunawan, 2017).

RESULT AND DISCUSSION

One of the essential steps in problem-solving is recognizing the problem-solving process as an organized decision-making process. This indeed requires a high cognitive ability. The decision taken would determine the relevance of their knowledge, by connecting existing knowledge with new experience, and assessing the knowledge needed to solve the problems faced (Ryan et al., 2016). This research uses virtual laboratories to increase students' problem-solving abilities. A comparison of the students' experimental and control group problem-solving test results in three different schools is shown in Figure 1 below.

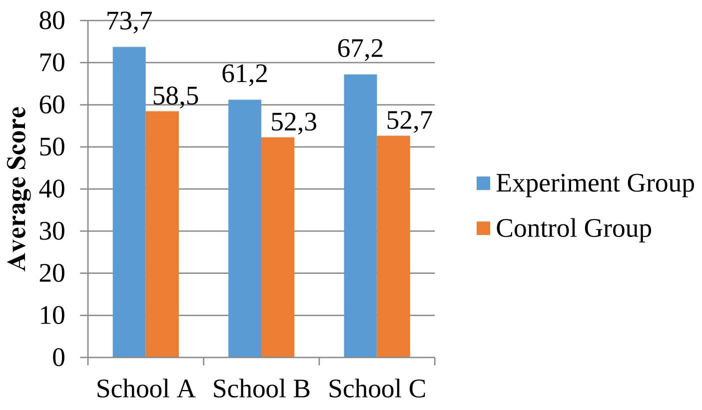

Fig. 1: Comparison of Average Score of Experiment and Control Class in Three Different Schools

Figure 1 shows that there are differences in average scores of students in three different schools. The experimental groups in the three schools scored higher on average than the control group. This suggests that with the use of a virtual laboratory in learning, better problem-solving skills can be achieved. In School A, the experimental group got an average score of 73.7, while the control group obtained a score of 58.5. This difference in scores indicates a significant difference in problem-solving ability between the experimental and control groups. Improvement of student problem-solving ability in the experimental group is in the high category, and the control group is in the moderate category. At school B, the experimental group obtained an average score of 61.2, while the control group obtained a score of 52.3. Both the experimental group and the control group have problem-solving skills that are categorized as a medium. At school C, the experimental group obtained an average score of 67.2, while the control group obtained a score of 52.7. This difference in scores indicates a significant difference in problem-solving abilities between the experimental and control groups. Student problem-solving skills at school C are included in the moderate category.

The research result in figure 1 shows that the use of virtual laboratory has a positive impact on students' problem-solving ability. A virtual laboratory can improve students' motivation and can develop students' various skill in measuring, processing, and identify problems. Problem-solving focuses on user's experiences and prior knowledge to think deeply and use cognitive skills to solve new problems at hand. This process does not only help in solving problems but also encourages students to interact/discuss with friends and develop cognitive skills (Hou et al., 2009). The result of this research is in line with research by Shute et al. (2016) which concludes that the use of computer simulations such as video games support the development of problem-solving skills. The use of virtual laboratories can also address some of the problems encountered in traditional laboratory applications and make a positive contribution to achieving the goals of the educational system. It is not always possible to see the result of students' study in real laboratory application, especially in inadequate laboratory condition. The use of a simulation program may address errors occurring as a result of laboratory limitation or abuses in laboratory practices (Tüysüz, 2010).

The virtual laboratory in this study is considered to have been able to develop students' thinking skills, especially to solve problems that start from the stage of identifying problems. According to the research conducted by Adachi and Willoughby (2013), virtual media such as video games have a positive impact on problem-solving ability and indirectly improve the academic achievement of each student. Students who have good problem-solving skills will have better knowledge. Furthermore, Kostic et al. (2013), revealed that the virtual laboratory could improve students' understanding of the fundamental concept of data analysis, problem-solving, and scientific interpretation. Another invention related to learning that utilizes information technology is Hwang et al. (2014), who state that web-based-problem solving approach is beneficial for students in guiding them to learn more effectively. The web-based-problem solving approach shows much better performance than those with a conventional problem-solving approach. In addition, Gunawan et al., (2017a) revealed that the use of virtual laboratories has a positive impact on students' problem-solving ability. Based on the analysis of problem-solving steps, students from experimental classes have good enough ability to identify problems, define goals, plan, and implement problem-solving solutions rather than control classes. The other research Gunawan et al. (2017c) concluded that there was an increase in creativity in students who have learned with virtual labs. Students were able to think divergingly to combine ideas verbally to an issue that is reflected in fluency, flexibility, and originality.

The problem-solving test in this study includes five steps which students must complete to obtain maximum result. These five steps follow the steps in solving physics problem proposed by Ferguson (2004) that include: step 1, identify and define the problem; step 2, define goals and objectives; step 3, generate a solution;

step 4, make a plan of action; and step 5, follow through. Assessment at each of these steps can help the teacher not only to determine the level of students' competence but also to know the students' strength and weaknesses on specific aspects of problem-solving. The average score of each problem-solving step in each school is shown in Figure 2 below.

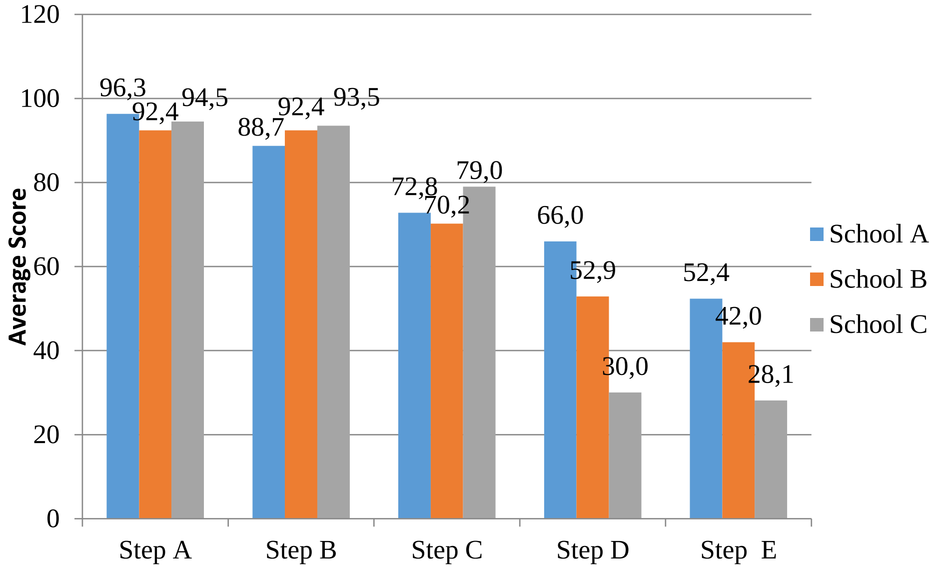

Fig.2 : Comparison of Scoring Result on Each Problem-Solving Step in Three Different Schools

Figure 2 shows that each school receives a different average score for each problem-solving step. In the first step, define and identify the problem, the score for school A is at 96.35, school B got 92.4, and a score of 94.5 was obtained by school C. In general, there is an increase in score in the three schools in the category of identifying and defining the problem. In the second step, define goals and objectives, school A scored 88.7, 92.4 for school B, and 93.5 for school C. This means that the increase in this category is high in all three schools. In the third step, generate a solution, school A scored 72.8, school B scored 70.2, and a score of 79.0 was obtained by school C. In general, an increase in this step is considered high in the three schools. The fourth step, make a plan of action, where school A obtained a score of 66.0, school B got 52.9, and school C could only score 30.0. Improvement in this step is moderate for school A and B, while for school C is categorized as low. The fifth step, follow-through, resulted in the obtaining of score 52.4 for school A, 42.0 for school B, and 28.1 for school C. In general, the improvement in follow through for school A and B is considered moderate, and school C is in a low category.

The research result in Figure 2 shows that students in all three schools manage to obtain an average score above the minimum criterion which is above 70 in the first three steps: identifying and defining the problem, defining goals and objectives, generating a solution. This result shows that the students were able to carry out the stage of identifying the problem until the planning phase of the problem-solving well. Students' success in the first step, identifying and defining problems, is characterized by students' ability to understand the language or words used in the problem and to formulate what is known and asked. Students are also able to assess whether the available information is adequate or otherwise, understand the conditions, and declare or write down the problem in a more operational form to make it easier to solve the problem.

The students' success in the second step, define goals and objectives, is characterized by student's ability regarding asking question-related to the purpose of problem-solving; developing a logical way of thinking to analyze the problem; and utilize images, specific patterns, or notes to determine the goal of the problem. Students' success in the third step, generate a solution, is characterized by students' ability in terms of formulating several ways or alternatives to the problem-solving solution and selecting one of the many solutions that have been formulated.

As shown in Figure 1, the highest problem-solving scores in all three schools are in the first two steps of problem-solving. The first step, identify and define the problem, and the second step, define goals and objectives, have a very good score, even close to perfect. The third step, that is generate solution, has been achieved by the students well but still, needs improvement. However, this trend does not apply to the last two steps namely, make a plan of action and follow through. Both of these previous two steps desperately need particular attention because they got the lowest score. The occurrence of this can be explained by the approach as follows:

Firstly, in the implementation of problem-solving in the first three steps, some students individually scored low. Some of these students did not have an excellent ability in identifying problem up to the stage where they plan and determine the solution. This caused them difficult to carry out the next steps and impact on the score they get. This statement is in accordance with Kar et al. (2010) which in his research assessed that prospective teachers who have difficulty in raising problem on a particular pattern would also hardly solve the previously proposed problem. This implies that students who cannot complete a particular step, will not certainly be able to complete the next step well.

Secondly, the decrease in the average scores of students in the fourth and fifth steps is because these last two steps require a higher level thinking analysis than the previous three steps. In the fourth step, making a plan of action, students are required to be able to analyze the choice of ideas to solve the problem and choose one of the many ideas as the right solution to do. Meanwhile, the follow through step requires students to provide the follow-up of the overall problem solving appropriately. When looked carefully, these two final steps are the most crucial steps and therefore need a more qualified logic and high-thinking order. Students who have not experienced working on problem-solving would face difficulty in implementing it. The result of this study is in line with Healey's (2005) statement which suggests that the fifth step requires high skills such as the development of problem-solving ability in which procedures are followed to formulate problem, perform the necessary calculation, and verify the logic used to see and assess whether the final answers make sense. In addition, Gunawan et al. (2018) reported that students were able to create creative ideas to solve the problem of static fluid.

Failures that are often experienced by students in solving problems merely occur because they do not have a good understanding of the problems at hand. Students' understanding of a problem depends on their experience in solving the previous problem. In fact, the ability to solve the problem can be obtained by students through diligently practicing solving problem, just as the physicists do. The more students work on problem-solving exercises, the more easly the pattern of problem-solving will be formed. As with planning for problem-solving, students can look for possibilities that can occur or recall problems that have been resolved, which have a similar nature to the problem to be solved. Therefore, it is necessary to set up the procedures for solving the problem. Based on the result of many studies, students who diligently practice problem-solving will have a higher problem-solving skill score that students who rarely practice or have never practiced problem-solving exercises. In addition, interest in facing challenges and the willingness to solve the problem is also a major capital in problem-solving.

CONCLUSION

The use of a virtual laboratory in physics learning has a positive impact on improving students' problem-solving skill in three different schools. In the three schools, the average score of the problem-solving ability of the experimental group is higher than that of the control group. The result of the analysis on each problem-solving step indicates that the students have the highest value in the first step, identify and define the problem. Students have an excellent ability in identifying problem up to plan for problem-solving, whereas for the step of analyzing the choice of ideas and step to follow up of problem-solving overall still need to be improved. Students who are unable to complete a particular problem-solving step will not be able to complete the next step well.

The findings of this study provide empirical evidence that the use of virtual laboratories in physics learning in secondary schools can improve student problem-solving skills. The results also show that at some point of problem solving, students are still experiencing difficulties hence help and habituation of problem solving should continue to be done. The findings of this study will reinforce the results of previous research on the importance of familiarizing students to learn to solve problems by the material learned in school.

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