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Guided Inquiry Method Employing Virtual Laboratory to Improve Scientific Working Skills

Siti Juwariyah[1)], **Soepriyono Koes H**[2)], **Eny Latifah**[2)]
[1)]SMKN 1 Panji, Situbondo
[2)]Physics Education–Universitas Negeri Malang
E-mail: siti_2333@yahoo.co.id

Abstract: There are many obstacles in achieving the goals of learning physics. One of those is how students' assumption on physics as something abstract and can not be verified by experiment, because of the unavailability of laboratory and equipment in schools. This study aims to assess if students' scientific work skills learned through Guided Inquiry method employing Virtual Laboratory is higher than those learned through conventional method. The research used quasi-experimental research method with the Non-equivalent control group design. The data was analyzed by using ANCOVA test. The results showed that when covariable controlled the prior knowledge, students' scientific working skill is higher with guided inquiry method employing virtual laboratory than those who learned through conventional learning.

Key Words: guided inquiry, virtual labs, scientific working skill

Abstrak: Banyak kendala yang harus dihadapi dalam mencapai tujuan pembelajaran fisika. Berdasarkan hasil studi pendahuluan, salah satu kendalanya adalah anggapan siswa bahwa materi fisika merupakan sesuatu yang abstrak dan tidak bisa dibuktikan kebenarannya dengan eksperimen di sekolah, karena tidak tersedianya peralatan laboratorium. Telah dilakukan penelitian yang bertujuan meningkatkan keterampilan kerja ilmiah siswa yang belajar dengan pembelajaran *guided inquiry* berbantuan Laboratory virtual. Metode penelitian yang di implimentasikan adalah kuasi eksperimen, dengan desain penelitian *Non-equivalent control-group design*. Analisis data menggunakan uji ANCOVA. Hasil penelitian menunjukkan bahwa setelah dikendalikan kovariabel pengetahuan awal, keterampilan kerja ilmiah siswa lebih tinggi pada siswa yang belajar dengan *guided inquiry* berbantuan laboratory virtual dibanding yang belajar dengan pembelajaran konvensional.

Kata kunci: guided inquiry, laboratory virtual

Learning Physics should basically adjust to how the previous physicist get the knowledge (Toth, *et al.,* 2008, p. 334). Physicists obtained that knowledge by applying their scientific working skill (Yang & Heh, 2007; Darrah *et al*, 2013; Crippen *et al*, 2012; Karlsson *et al*, 2012). Broadly speaking, the process of scientific working steps done by physicists covers all these points, which are: (1) observing every phenomenon existed around us; (2) questioning why the phenomena could possibly happen (called as proposing the problem); (3) Constituting hypothesis to answer the problems proposed and explaining the reasons (4) Planning an experiment in order to test the hypothesis (5) Conclusions making whether or not the hypothesis is right according to the experiments (Toth *et al*, 2008; Yang & Heh, 2007; Crippen *et al*, 2012).

Recently, some obstacles found to be hindered in achieving good scientific working skill as a goal of physics learning activity. The 2013 curricula suggested that scientific approach is one suitable method to be applied from the very first place (Kemendikbud, 2013). The utilizations of the laboratory in the experiment has a very close relationship to a scientific approach since physicists found every single physics theory and all its complements through experiments (Toth, *et al*. 2008). Unfortunately, according to the previous studies, some schools are not equipped with proper tools which can be used to do some experiments, even more, there is no laboratory to cover the needs, as what happens

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in SMKN 1 Panji. It makes students see physics as something abstract which its' validity cannot be proven through experiments (Kozhevnikov *et al*, 2013; Crippen *et al*, 2012). This paradigm makes the students find a hard time mastering the concepts and their scientific working skill which was proven by their average scores of 65,82 in final school examination with practical examination average score of 64,56.

Knowledge and technology development had taken this problem into a better stance of settlement. With only a few laboratories and even fewer tools to be used, technology creates virtual laboratory which could basically help these students to experiment easier. It covers all the lacks such as tools, limited time to do the experiments, cost for trials and reduction of practical experiment effect (Tang & Heh, 2007; Karlsson *et al.,* 2012; Darrah *et al*., 2012). Through virtual laboratory, all aspects included, like buildings, tools, and physical substances, are all imported to computer-based object or software in the virtual laboratory (Crosier *et al*., 2000). Because basically, this virtual laboratory is a prototype of a laboratory in a form of computer software under the basis of interactive multimedia which can be utilized through computers, or even cell phone, and stimulate the real activities as if the users are using the real laboratory (Karlsson *et al*., 2012; Crippen *et al.*, 2012; Shegog *et al.,* 2011). Fortunately, students in SMKN 1 Panji are obliged to have a laptop that everyone can get the same chances of trying. Technology and information development makes the computer a cognitive medium to support students learning activity in scientific investigation (Barko & Sadlesr, 2012).

Guided inquiry method is a type of learning where students work by themselves (constructing hypothesis, experimenting, testing the hypothesis, and concluding) but still are assisted and guided intensively by teachers, in order to find the answer to the problems. Besides, Guided inquiry method emphasizes the idea of students should be active on behalf of developing their scientific working skill to construct questions which are directed to investigating, hypothesizing, experimenting, gathering and processing the data, and communicating the result of the experiments within the learning process (Rizal, 2014, p. 161). Fundamentally speaking, guided inquiry method was originally adopted from an experiment of information searching processes which show the students' learning processes through any kinds of information resources in particular projects provided (Kuhlthau, *et al*., 2012). Guided Inquiry method can basically promote new knowledge acquisition, skill and independent behavior through investigations, questions, and problems which need answers (Lee, 2012:6). Even further, this kind of method can basically improve students' critical thinking and creativity that they could understand all materials well (Acakpovi, *et al.,* 2014). Guided Inquiry method is conducted through 5 steps of working, which are 1) Investigating the problem, 2) Constructing a hypothesis, 3) Experimenting, 4) Hypothesis testing, and 5) Decision making (Wenning, 2011).

According to some cases, the result shows that Guided inquiry method has some advantages like, the process of the learning can be more innovative, a more manageable groups for the teacher, students are motivated to learn and they are also motivated to think scientifically and solving their own problems (Toth, *et al*., 2008). Guided Inquiry method is quite superior for some reasons like 1) improving students' intellectuality, 2) improving students' internal motivation to learn, 3) Deriving students to think inductively or we usually call it an investigation, and 4) improving students' memory durability (Wenning, 2011). Guided inquiry method can also help students to be more critical and creative (Acakpovi, *et al*., 2014). Therefore, through this explanation, a conclusion can be drawn that Guided inquiry method is capable of 1) improving students scientific skill, 2) improving students' learning result, 3) improving students' mastery on concepts, 4) improving students' scientific working skill, 5) improving their critical thinking skill and help them to be more creative.

A virtual laboratory is a computer program which can visualize abstract phenomena or complex experiments and also improve the learning technical program significantly. A virtual laboratory is a series of program visualizing abstract phenomenon and complex experiments done in real life activity which can basically improve the learning situation and develop the students' skills needed in solving the problems (Boujaoude & Jurdak, 2010). In the other side, a virtual laboratory is a series of laboratory tools in forms of software based on interactive multimedia, which can be operated through computer and has the capability of simulating the real activity just like what it should happen in real life (Karlson, *et al.,* 2012; Crippen, *et al.,* 2012; Shegog, *et al.,* 2011). A virtual laboratory is similar to simulation laboratory which can improve the technical teaching and learning program significantly (Acakpovi, *et al.,* 2104, p. 142). Basically, a virtual laboratory provides you the way to learn and present the result through computer simulation (Choudhary, 2014).

This research employed virtual laboratory software from Kemendikbud in *U-pipe* experiment and a virtual laboratory created by the University of Colorado with a website address of *http://phet.colorado.edu*. Trough this website, we can download the application for free which provides you some options of languages since students and teachers in this particular place are short in English.

Scientific works were defined to be systematical efforts to get the answer to the problem by using the scientific method of logical thinking and observation (Yang & Heh, 2007). Generally, the process of scientific learning done by physicist covers these steps as (1) observing the phenomena existed (literature exploration); (2) proposing questions of why this phenomenon can happen (constructing problems); (3) constructing hypothesis to answer the problems given and explain the reasons why; (4) planning an experiment and analysing the result; (5) the process of decisions taking in order to know the truth comes from the hypothesis according to the experiment (Ariesta and Supartno, 2011:62). In planning the experiment, some indicators are established, such as 1) constructing the goal of the research, 2) variable taking, 3) determining its' bound variables and free variables (Depdiknas, 2003). In doing a research in physics, some competencies should be existed, like 1) preparing the right and appropriate tools for the research, 2) precisely using the equipment, 3) analyzing the data, and 4) concluding the result of the research.

A type of method which supports scientific investigation through virtual laboratory is guided inquiry method. This type of learning helps students to develop their scientific thinking patterns and train them to be a good problem solver along with their analytic capability which could make them understand the basic concept of physics easier (Slekiené dan Ragulienè, 2013, p. 134). In other words, Guided inquiry method has the ability to develop the student's willingness and motivations to learn physics principals and concepts (Sari & Yilmaz, 2015, p. 609) Moreover, guided inquiry method provides bigger chances for students to experience more (Lee, 2012). Therefore, guided inquiry method helps the students constructing physical concepts they have learned through thinking processes and scientific working skills used in an investigation employing virtual laboratories.

Guided inquiry method employing virtual laboratory is expected to help students in the concept of fluid. In dynamic fluids, students usually see it hard to understand and imagine fluid's movements in learning the basic theory of dynamic fluids (Benigno, *et al*., 2015). Students need pictures, animations or even videos to make them understand the theory well that Dynamic Fluid material should be something which could portray all scientific phenomenon in one package (Benigno *et al*., 2015:49). In the virtual laboratory, students can visualize physics phenomena and its' concepts related through animation in microscopical level, along with related simulations and all examples happen in daily life, not to mention stimulating more students to reach a higher level of understanding upon physics concepts (Russel *et al*., 1997, p. 330).

Some researchers like Yong & Heh (20017); Darrah *et al.,* (2014); Crippen *et al*., (2012); and Karlson *et al.,* (2012) found out that there is a positive influence brought by virtual laboratory upon students' mastery of the concepts and scientific working skills. Yong & Heh (2007) believed that virtual laboratory can basically improve students' academic achievements and scientific skill processes even when it has different instructions and treatments as the traditional one. The research was done for Mechanical Engineering subject, Electricity and Optical Engineering. Other than that, Darrah *et al* (2014) showed that virtual laboratory has the same result which is as effective as an instructional traditional laboratory in kinematics material under the 5th theme of E-Cycle. A research was done previously through computer simulation in order to find the solution to overcoming students difficulties in static fluid concepts mastery, but unfortunately, it was focusing on misconceptions only (Fraser *et al*., 2007).

Guided inquiry method employing virtual laboratory is proposed to be able to train students scientific working skills in fluid materials done through an investigation. Hence, it is very important to do an experiment to test "Guided Inquiry Method Employing Virtual Laboratory to Improve Scientific Working Skills."

The hypothesis proposed for this research was settling on how by controlling the students' pre-test, can a guided inquiry method employing virtual laboratory increase students' scientific working skill better than using the conventional one?

METHOD

This quasi-experimental research used two groups of samples which are, experimental group and control group. An experimental group is a group equipped with guided inquiry method employing virtual laboratory, while the control group is a group equipped

with conventional laboratory through Direct Instruction as it is usually used in SMKKN 1 Panji. The design used in this research was a Non-equivalent control group design.

The population taken for this research was all students in the 10th grade under the major of Communication and Information Technology consisting of 4 groups, which are X MM, X RPL, X TKJ 1 and X TKJ 2. Samples for this research were taken randomly, the groups were chosen through cluster random sampling method. This kind of sampling technique is usually used to decide and chose the samples when the number of the samples needed in the research is quite numerous. The group which was treated differently and called to be the Experimental Group is X RPL. Another group treated as it usually does and called to the Control Group is X TKJ 2. In the next step, both groups were taught by the same teacher with a different way of teaching. The teacher thought the experimental group with guided inquiry method employing virtual laboratory while in the control group she taught the students through conventional method.

Instruments used in this research was developed by the researcher herself in two different forms, which were an instrument for treatment and instrument for scoring. The first instrument, which was made for treatment processes covers Syllabus, Lesson Plans, and Students Worksheets formulated based on 2013 curricula. While the second instrument covers all pre-test materials consisting of 15 multiple-choice questions about concepts mastery and 6 questions about scientific working skills which should be answered within some sentences.

Statistical analysis in this research was consisting of prerequisite testing and hypothesis testing. Prerequisite testing process covered homogeneity test and normality test. The homogeneity test was done through *Levene* test and the normality test was completed through *Kolmogorov-Smirnov* test. The hypothesis testing was done through ANCOVA with prior knowledge covariate.

RESULTS

The Description of the Research Data

The data of the research are the pre-test data and scientific working skill data. Both data are described as follows.

Pre-test

Pre-test scores were taken through the testing instruments in fluids material. The instrument had 15 multiple-choice questions. The test was given before the treatment started. The complete pre-test data of experimental group and control group are described in Table 1.

Table 1 shows that students' pre-test scores in the experimental group through guided inquiry method employing virtual laboratory has the average score of 42,2 while in control group got the average score of 32,3. Both pre-tests were taken within the same minimum scores but then have different maximum scores.

Scientific Working Skill Data

Scientific working skill scores of the students were taken from the instrumental test in fluid materials consisting of 6 questions answered in short essays. The test was given right after the treatment was done. The data of the test were described in Table 2.

Table 2 shows different average scores for scientific working skill between the experimental group and the control group. The experimental group which was taught through guided inquiry method employing virtual laboratory got the average score of 70,4 while the control group marked it in the point of 43,2.

Table 1. Pre-test

Group	N	Minimum Score	Maximal Score	Average Score	Std. Deviation	Std. Error
Experimental	32	13	73	42,4	17,04	3,01
Control	32	13	60	32,3	13,13	2,30

Table 2. Scientific Working Skill

Group	N	Minimum Score	Maximal Score	Avg	Std. Deviation	Std. Error
Experiment	32	23	100	70,4	22,06	3,89
Control	32	7	79	43,2	18,23	3,22

Prerequisite Analysis Test

Some requirements constituting the utilization of statistical technique were tested before it is used to test the hypothesis. Prerequisite test within analysis technique covers normality test and homogeneity test.

Normality test

Normality test was conducted during the research in order to find the information if each variable taken to be the samples has the data which were distributed normally. Normality test in this research was done for pre-test data and scientific working skill data which were taught through both guided inquiry learning method employing virtual laboratory and the conventional method. Normality test was done through *Kolmogorov-Smirnov* statistic system within 5% of significance level. The result of the normality test can be seen in Table 3.

According to Table 3, the pre-test data with a significance level (sig.) of 0,178 in the experimental group is bigger than 0,055 in control group. It means that H_0 can be accepted, thus it can be concluded that the pre-test data came from a population with a normal distribution. The experimental group' scientific working skill data in Table 3 shows significance level of 0,200 while in control group shows significance level of 0,84. These two scores are bigger than 0,05 which means that H_0 is accepted and can be concluded that both data of scientific working skill were taken from populations with a normal distribution. According to that normality test, it can be concluded that the pre-test data and the scientific working skill data came from populations with a normal distribution.

Homogeneity Test

Homogeneity test was used to find out whether or not these two kinds of data have the same data variations. In this research, homogeneity test through *Test of Homogeneity of Variance* with a significance level of 5%. The result of the homogeneity test can be seen in Table 4.

Interpretation for deciding homogeneity was done by choosing one statistical system *Based on Mean*. In Table 4, the test which was done using statistic *Based on Mean* with pre-test data resulting on a significance level of 0,398 which is bigger than 0,05. Hence, it can be said that H_0 is accepted and decipherable said that the variation of every sample in pre-test are the same or homogeneous. On the data of scientific working skill, the number of 0,170 was shown up to be the significance level of the statistic system *Based on Mean*, which is bigger than 0,05 and H_0 are accepted. Through these data, variations in every sample of scientific working skill are said to be homogenous too. By virtue of these homogeneity test, it can be concluded that pre-test data and scientific working skill data have the same variation or homogenous.

Data Analysis

According to the result of the pre-requisite test, it shows that pre-test data dan scientific working skill data were normally distributed and have the same

Table 3. Tests of Normality

		Kolmogorov-Smirnov[a]			Status
	Group	Statistic	df	Sig.	
Pre-Test	Experimental	.131	32	.178	Normal
	Control	.153	32	.055	Normal
KKI	Experimental	.113	32	.200	Normal
	Control	.145	32	.084	Normal

Table 4. Test of Homogeneity of Variance

		Sig.	Status
Pre-Test	Based on Mean	.398	Homogen
KKI	Based on Mean	.170	Homogen

Table 5. Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
The Learning	11849.218	1	11849.218	20,63	.000

variation or homogeneous. Since the prerequisite test was completed, therefore a hypothesis testing using parametric analysis of ANCOVA helped by SPSS 16.0 for windows was ready to be accomplished. The results can be seen in Table 5.

The result of the ANCOVA test in Table 5 was used to test the hypothesis as follows.

$H_0 : \mu_1 = \mu_2$ (Controlled by pre-test co-variable, students' scientific working skill with guided inquiry method employing virtual laboratory has the same level as those employing conventional method).

$H_1 : \mu_1 \neq \mu_2$ (Controlled by pre-test co-variable, students scientific working skill improves higher with guided inquiry method employing virtual laboratory than those employing conventional learning method).

The group's data (experimental and control) for scientific working skill in Table 5 shows that F is 20,63 with a significance level of 0,000. The significance level is smaller than 0,05, means that H_0 is refused and H_1 is accepted. Hence, it can be concluded that being controlled by pre-test co-variable, students' scientific working skill improves higher with guided inquiry method employing virtual laboratory than those with the conventional method.

DISCUSSION

Based on the result of the research, scientific working skill in the experimental group has a higher average score of 70,4 compared to control group with only 43,2 average score. After the prerequisite test was done, an ANCOVA analysis was started right away. The result of the prerequisite test shows that the data was normally distributed and each variation is homogeneous.

The result of the ANCOVA analysis can be used to answer the second research hypothesis on how scientific working skill showed that F is as much as 20,63 with a significance level of 0,000. The significance level was lower than 0,05, therefore H_0 was refused and H_1 was accepted. Hence, it can be concluded that controlling the prior knowledge through its co-variable, students' scientific working skill taught through guided inquiry method employing virtual laboratory should basically have a higher mark than those taught through the conventional one.

According to the hypothesis analysis result, an answer was deployed that scientific working skill taught through guided inquiry method employing virtual laboratory within the experimental group during fluid material shows a better result compared to those taught through conventional method within the control group. Therefore, we can say that the difference in scientific working skill is significant enough between both groups and it happens because of different treatment was given during the process of the research.

Scientific working skill in guided inquiry method employing virtual laboratory shows a better result compared to those in conventional method by controlling the prior knowledge. It happened because scientific working skill can actually be trained to students in every step of guide inquiry learning method employing virtual laboratory. Therefore, it suits the result of the research which says that guided inquiry method employing virtual laboratories can help students to train their cognitive skills in finding out the problems, not to mention solving it through scientific working skill too (Yang & Heh, 2007). Scientific working skill in this research covers 1) constructing problems, 2) making a hypothesis, 3) analyzing data, 4) decision making.

On the first step of guided inquiry method employing virtual laboratory aims to develop the students' scientific working skill in constructing problems based on the phenomena happened around them. In developing the students' scientific working skill, teachers provided some phenomena related to the material to be taught. Students were allowed to ask some yes-no questions (only) related to the phenomena to teachers. Teachers answered the students with yes or no so that students will later construct their own knowledge through their own questions previously. This activity developed students skills in problems constructing related to the material existed. The result on this part of the research is in line with the previous research theory claiming that students can develop their critical and analytical thinking skill by asking many questions about the problems or constructing it (Toth, *et al*. 2008)

Scientific working skill in constructing hypothesis can be developed further through the second step of guided inquiry method employing virtual laboratory. In this step, students construct their own hypothesis from the problems they have in the previous step according to theoretical frameworks and teachers guidance. Students were discussing to make the hypothesis, while teachers guide the students that their hypothesis should be directed to answer the problems. Through this activity, students are capable of thinking critically, not to mention, developing their mindset on making hypothesis correctly. It goes the same way with an opinion stated that students learning activity in constructing hypothesis can definitely develop their critical thinking skill (Lee & Tsai, 2012).

The third step of guided inquiry method employing virtual laboratory is that doing the experiment using the virtual laboratory. This experiment was done to gather the data needed to be analyzed. This activity did not need that much time to gather the data, students can also repeat the experiment for many times in order to find the most suitable and valid data. Some benefits were going along with the process. For example, through virtual laboratory, the activity can be completed safe and sound. Students will stay clean for the whole time since there is no risk of being wet in measuring the hydrostatic pressures deep down of the container full of water or measuring the leakage flows within. It suites one idea which says that virtual laboratory provides better safety level than the conventional one. The time needed is also manageable to do the experiment that it can be repeated when necessary (Toth, *et al*., 2008). However, virtual laboratory is no longer effective to help students master the real application of both simple and sophisticated measuring scales (Boujaoude & Jurdak, 2010)

Developing students' capability in analyzing through scientific working skill can be done in the fourth step of guided inquiry method employing virtual laboratory. The learning activities of testing the hypothesis should be done through analyzing the result of the experiment and discuss it together with teachers and friends in the group. Teacher guides the students to evaluate the hypothesis and give away some questions which are directed to test the hypothesis. Students should analyze the result of the experiment and discuss the the hypothesis the have made before to be compared with the result of the experiment and literature. This activity can basically enhance students' capability to logically, analytically, and critically think, not to mention testing the truth deployed by the hypothesis (Yang & Heh, 2007; Darrah, *et al*. 2014).

Another stage to go is that developing the students' scientific working skill in making conclusion should be taken into the fifth step of guided inquiry method employing virtual laboratory. In this step, students are encouraged to conclude all the materials they have got during the day helped by teacher's guidance and later the teacher should emphasize the real concept of all. Through this step, students improve their conclusion making skill according to the result of the experiment and analysis to test the hypothesis and packed it into one complex conclusion. This is the process where students develop their thinking skill along with improving their sense of responsibility in taking any decision (Boujaoude & Jurdak, 2010).

By virtue of the previous explanation, we can conclude that guided inquiry learning activity employing virtual laboratory can keep the student's skills and the ability to contract problems ahead, even solving it through their own experience (the experiment). Since they should put the teacher aside from the main resources of answers, they will see teachers as their facilitator instead. In another hand, the application of scientific working skill in control group learning activity was done through the phase of structural practices with the teacher, therefore they put teacher as the main resources of answers and solutions. Hence, the application of guided inquiry method employing virtual laboratory seems to be more effective in creating a critical, logical, analytical and creative student compared to the conventional method they have ever gone through which relying too much on teacher as the main resources of answers, letting them be passive and less creative (Boujaoude & Jurdak, 2010); Darrah *et al*., 2014). As the previous description above, it can be concluded that students' scientific working skill using guided inquiry method employing virtual laboratory is higher than those in control group with the conventional method.

CONCLUSION AND SUGGESTIONS

Conclusion

Based on the result of the research, we can conclude that students' scientific working skill taught by guided inquiry learning method employing virtual laboratory in the material of fluid gets higher and better improvements compared to those studying it through conventional method.

Suggestions

From all those explanations above, some suggestions are generated for the greater good of the further research. They are, (1) Teachers are suggested to apply guided inquiry method employing virtual laboratory when the school provides no laboratory or in a very short number of tools to use during the experiments. Because this method is quite easy to apply since the software can be put in the students' laptop or even cell phone, which is equipped with the android system. This kind of method is very helpful to enhance students' mastery of concepts and scientific working skills. (2) Time management is matter. The goal of the learning can never be achieved well when the

time management is messy. Things like preparing all the equipment needed, for example, *Phet Simulation* software installed and ready to be used, a fully charged battery, and how the process of the learning will happen continuously. It will be even better if the teacher can explain the flow of the learning from the very beginning of the lesson until the very end of the activity that students can be fully focused on the lesson. (3) There should be further research about the effect of guided inquiry method employing virtual laboratory concerning the students' misconceptions upon physics.

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