Implementation of virtual laboratory through discovery learning to improve student’s physics competence in Senior High School

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Abstract. One of the problems in physics learning in schools is the low competence of students both in the cognitive and skills competence. One of the solutions to improve the competence of skills is using real and virtual practicum. Improving cognitive competence use discovery learning. The purpose of the study was to determine the effect of implementation through discovery learning in senior high school. To achieve the purpose of research, it used quasi experimental research. The population of the study was students of SMAN 1 Padang and the sample was two classes with cluster random sampling technique. Based on the results of data analysis, it got average learning outcomes which experimental class is 78.5 and a control class is 70.5. By using t-test statistic, it got t-count 3.96 and t-table 2.00. It mean t-count was bigger than t-table. It can be concluded that there was a significant influence in the application of virtual laboratory through discovery learning in senior high school to student’s physics competence in credibility rate 95%.

1. Introduction
One of the causes of low student achievement in learning is the limited of laboratory facilities in secondary schools in Indonesia, whereas laboratory activities are important to build meaningful learning in students. The laboratory serves as a place to test, examine and prove existing theories, sometimes in a school environment; the state of the laboratory does not have adequate facilities and infrastructure. Based on the observations in senior high schools in Padang, the results showed that most schools did not have complete practicum facilities to support the 2013 curriculum implementation so that there were not many practicable concepts to be practiced, consequently many concepts was neglected in learning. Based on the experience of researchers in the 2015 competitive grant research on the development of teaching materials, there were several weaknesses in learning at school, including when the Student Worksheet for the practicum was designed in accordance with the curriculum requirements, the practicum could not be done because there were no facilities available.

Theoretically, the learning process in the classroom and in the laboratory includes developing three competencies, namely cognitive, effective and psychomotor. To achieve these three domains, a balance is needed between the delivery of theory and practicum activities. Especially in certain concepts, practicum is needed. It can happen because the activities in the class only assessing cognitive competence while practicum can include assessment of students’ affective and psychomotor competencies. Activities in the classroom and in the laboratory in the learning process are inseparable because they are interrelated between one another to achieve the goals in the learning.
One solution to provide meaningful learning skills within the limitations of laboratory facilities and infrastructure is to do virtual labs. This virtual practicum is an alternative model in overcoming the problem of practicum implementation in schools which sometimes requires a lot of time and expensive costs. This virtual practicum requires a virtual laboratory. Virtual laboratory (virtual lab) is one of the ICT-based learning processes that can be used as an alternative solution to learning by practicum methods. Virtual lab-based learning is one of the superior products from the advancement of information technology and laboratories. In learning activities, teachers should help students to develop their understanding by providing: direction and organization to learn, motivation to learn, explanation of concepts that are not easily learned by students themselves [1].

Based on the results of the research that has been done, it is obtained an illustration that students are more motivated to learn the concept of physics when accompanied by visualization of abstract concepts [2]. The most ideal virtual lab is run on the internet, so participants can experiment where and whenever. With virtual labs, buildings and physical laboratory equipment are converted into computers and virtual lab software [3]. Based on that, it is clear that virtual labs can be used as alternatives to help humans improve human productivity and welfare, complete problem, estimate how many options to complete and implement the solution. The virtual lab used in the study has been validated by experts in their respective fields [4].

The benefits of the virtual laboratory are 1) reducing time constraints, if there is not enough time to teach all students in the laboratory until they understand; 2) Reducing geographical barriers, if there are students whose location is far from school; 3) Economical, does not require laboratory buildings, tools and materials as in conventional laboratories; 4) Improve the quality of experiments, because it allows to be repeated to clarify doubts in measurements in the laboratory; 5) Increasing the effectiveness of learning, because students will spend more time practicing repeatedly; and 6) Improve security and safety, because they do not interact with real tools and materials [5].

To make use of the virtual lab effective, a discovery learning is applied. Discovery is a learning model where the teacher gives students the freedom to find something by themselves because by finding their own, students can understand better of what they learn. In discovery learning, students play an active role in the learning process by: (1) answering various questions or problems and (2) solving problems to find basic concepts. The teacher’s role changes from presenting information and concepts to inviting students to ask, see and search for the information themselves, thus changing the teacher center paradigm to become a student center. Discovery learning help students build cognitive based on pre-existing cognitive. In discovery learning, concepts are not presented in the final form, but students are encouraged to identify what they want to know and find information themselves. The information obtained is then constructed in a final form so that the cognitive found by students becomes meaningful learning.

Discovery learning is learning models that match the characteristics of physics learning. Physics learning is the process of obtaining information with the empirical method through an investigation that has been arranged logically and systematically, and is a combination of critical thinking processes that produce reliable and valid information. Physics as a process / inquiry method includes ways of thinking, affective, and steps of activities of scientists to obtain scientific cognitive products, such as observation, measurement, formulating and testing hypotheses, collecting data, experimenting, and predicting [6].

The steps of discovery learning include: 1) stimulation; at this stage students are faced with something that causes confusion, then continues to not give generalizations, so that the desire arises to investigate itself; 2) problem statement that is to give students the opportunity to identify as many problems as possible relevant to the lesson, and choose one to formulate (hypothesis); 3) data collection; this stage serves to answer questions or prove the correctness of the hypothesis; 4) data processing; an activity of processing data and information that has been obtained by students both through interviews, observation, and so on, then interpreted; 5) verification; at this stage students examine carefully to prove whether the hypothesis is determined by alternative findings, linked to the results of the data that has been processed; and 6) generalization is the process of drawing conclusions that can be used as general principles and applies to all the same events or problems, taking into account the results of verification [7].

Based on several previous relevant studies, the application of Discovery learning and the use of virtual labs in learning can improve students’ physical competence. Therefore, in this study, it was seen the effect of the application of discovery learning using virtual labs on the achievement of students’ physical competence in SMAN 1 Padang.
2. Methodology

This research is a Pre-Experimental Designs research. Pre-Experimental Designs research still has external variables that influence the formation of the dependent variable. The population in this study was all students of class X MIA SMAN 1 Padang. Sampling is done by purposive sampling technique by setting two sample classes.

The instrument used in this study is an instrument on affective, cognitive, and skills. Assessment of affective competency is done through observation techniques, use observation sheets made at each meeting in the classroom. Assessment of students’ cognitive competencies is done through post-test at the end of the study. Assessment instruments on cognitive competencies are multiple choice questions with five answer choices. Competency skills assessment is carried out when practicing. The instrument used is a scoring rubric. Aspects assessed are adjusted to the practicum carried out.

Data analysis techniques used for affective and skill competencies are expressed in descriptions. Cognitive competency was analyzed by using the influence test, namely the r test to see the effect of the treatment given.

3. Result and discussion

3.1 Result

The data in this study includes three competencies namely affective, cognitive and psychomotor competencies. Affective competency data were obtained during the face-to-face learning process in the classroom through observation sheets, cognitive competency data were obtained through written tests in the form of posttest at the end of learning, and psychomotor competency data were obtained during practicum through scoring rubrics on performance.

3.1.1 Affective Competence. The affective competency values after being analyzed for eight meetings in both sample classes can be seen in Figure 1.

![Comparison of Attitude Values for Experimental Class and Control Class](image-url)

Based on Figure 1, it can be seen that the average value of affective competency in the experimental class for each aspect of assessment is different from the control class. So, based on the analysis using graphs, it can be concluded that there are differences in the affective competency values of the experimental class with the control class.
3.1.2 Cognitive Competence. Description of cognitive competency data obtained from research is shown in Table 1.

Table 1. Description of Cognitive Competence Values for Experimen Class and Control Class at SMAN 1 Padang

|                | Experiment class | Control class |
|----------------|------------------|---------------|
| N              | 31               | 31            |
| Mean           | 68.04            | 60.65         |
| Std. Deviation | 6.15             | 8.38          |
| Variance       | 37.84            | 70.24         |
| Minimum        | 53               | 47            |
| Maximum        | 80               | 77            |
| Sum            | 2109             | 1880          |

Based on Table 1, it can be seen that the average value of experimental class cognitive competence is 68.04, the average value for the control class is 60.65, the experimental class standard deviation is 6.15, the control class deviation standard is 8.38 minimum and maximum values of the experimental class 53 and 80, the maximum and minimum values of control classes 47 and 77. The data obtained by the average value of the experimental class is higher than the control class.

The results of the hypothesis testing using the t-test for cognitive competence at a significant level of 0.05 obtained 3.96, while the value of t-table obtained 2.00 in the degree of freedom 62 with a significance level of 0.05. Based on the t-test data obtained, it shows that it is outside the Ho acceptance area, meaning that there is a difference in the cognitive competence of the experimental class with the control class. The difference is because there is an influence of the application of the discovery virtual learning assisted learning model on the achievement of students’ cognitive competencies.

To find out the magnitude of the effect of the application of a virtual laboratory in discovery learning, a simple linear regression test with the equation obtained is:

\[ \bar{Y} = a + Bx = 75.37 - 0.085X \]  
(1)

While the significance test and linearity test obtained results as in Table 2.

Table 2. Anava for Regression of Cognitive Competencies

| Source of Variance | df | Square Amount | Total Square | F      |
|--------------------|----|---------------|--------------|--------|
| Total              | 31 | 144744.44     | 144744.44    |        |
| Coefficient (a)    | 1  | 143616.13     | 143616.129   | Fh = 0.867 |
| Regression (b/a)   | 1  | 4.419         | 4.419        | Ft = 4.18   |
| Residual           | 29 | 1123.896      | 38.3755      | Fh < Ft    |
| Total Residue      | 16 | -4.419        | -0.276       |        |
| Error              | 13 | 1128.315      | 86.793       | Fh = -0.003, Ft = 2.70 |
|                    |    |               |              | Fh < Ft, rh = 0.06 |
Based on Table 2 for the significance test obtained the value of $F_{\text{count}} = 0.867$ is smaller than the value of $F_{\text{table}} = 4.17$, meaning that the coefficient of regression direction is not significant. For the linearity test, it is found that the $F$-value is smaller than the $F$-table value, which means that the regression value is linear. To test the relationship between two variables, it is obtained that $r_{\text{count}}$ is smaller than the value of $r_{\text{table}}$. It means that there is no relationship between the application of discovery discovery models using virtual labs to the achievement of knowledge competencies.

3.1.3 Psychomotor Competence. To find out the magnitude of the effect of the application of discovery assisted virtual lab models in Discovery learning using simple linear regression test with the following equation:

$$\hat{Y} = a + Bx = 1.209X-17.257$$

While the significance test and linearity test can be assisted with Anava Tables.

| Source Variance | dk | JK         | KT         | F          |
|-----------------|----|------------|------------|------------|
| Total           | 31 | 229931.25  | 229931.25  |            |
| Coefficient (a) | 1  | 232958.6   | 232958.6   | $F_h = 391.487$ |
|                 |    | 74         | 74         | $F_t = 4.18$ |
| Regression (b/a)| 1  | 894.240    | 894.240    | $F_h > F_t$ |
| Residual        | 29 | 66.242     | 2.284      |            |
| Sum Total       | 16 | -894.240   | -55.890    |            |
| Error           | 13 | 960.482    | 73.883     | $F_h < F$  |

Based on the results of the analysis in Table 3, for the significance test, the $F$-count value is greater than the $F$-table value, meaning that the coefficient of the direction of the regression means. For linearity test, the $F$-value is smaller than the $F$-table value, which means linear regression. To test the relationship between the two variables, it is obtained that $r_{\text{count}}$ is greater than the value of $r_{\text{table}}$, this means that there is an effect of the application of discovery models using virtual labs to the achievement of skills competencies. To find out the influence of the application of discovery learning with virtual labs on the achievement of student skill competencies, the determination coefficient is calculated. From the calculation results obtained the coefficient of determination of 93.10%, meaning 93.10% of skills competencies are influenced by the influence of the application of discovery models using virtual lab.

3.2 Discussion
Based on the results of data analysis for affective competence, it was found that the average affective shown by students tends to change. For spiritual indicators, affective observed were limited to the students’ habits of greeting and praying at the beginning and at the end of learning. Students do these habits as a necessity and not based on awareness. In the indicator of discipline, students still cannot show consistency. The discipline referred to in this study is the habit of students entering the class on time. This lack of discipline is caused by the time during class hours during the day, which is 1 hour before the noon prayer break and 2 hours after the break. Students who are too late have not praying and lunch because of the long queues in the canteen and the mushalla.
Students’ curiosity is observed at the stage of stimulation and problem statements. Students who have high curiosity observe enthusiastically the stimulation provided and tend to ask questions about something they observe. In vector physics material for the first-four weeks, students’ curiosity increases. This is because students are given stimulation using animation on ICT teaching materials that are aired using projector with not in their entirety, giving rise to greater enthusiasm and curiosity to investigate the students themselves. This curiosity is also caused because vector material is new material to students, so students have a great curiosity. In straight-motion material during the next four meetings, students’ curiosity actually decreases.

In the indicator of self-confidence, students show lack of confidence. Assessment of students’ confidence is taken at the stage of the problem statement and generalization or drawing conclusions in discovery learning s. Students who are confident will immediately raise their hands when asked to questions or to draw conclusions at the end of learning, while others only record conclusions in the notebook without being communicated or delivered in the forum orally. Lack of confidence in students is caused by students not accustomed to submitting opinions or questions in learning. The highest self-confidence of students is shown at the fourth meeting; after practicing vector material. Each student is required to make an opinion or question to be delivered during the discussion after the practicum is carried out. After several meetings, students’ confidence was showed again. This confidence arises when every student is given a time and must to express opinions in learning, whereas if it is not an obligation, then the average student tends to only hear his friend’s opinion.

The hard work of students is shown at the stage of data collection and data processing in discovery learning s. Students show a tendency to work hard on new material. This is evident from the highest average value of hard working students shown at the first meeting; the introduction of vector material. Because they felt the material had just been learned, students showed high hard work. Overall students have shown an affective in good criteria during learning for each assessment indicator. Although the affective of students is not consistent, but with the guidance and demands of affective such as having to work hard, have confidence and high curiosity, students will be motivated to have a better affective. This is also one of the positive effects of Discovery learning. The use of conventional learning models in previous material causes passive students so that expected social affective become less developed, such as curiosity, confidence, and hard work. The use of ICT teaching materials in learning activities also adds to students’ curiosity and interest in learning because students are faced with a variety of activities and varied media. So, the use of Discovery learning assisted by ICT teaching materials can improve students’ affective competencies towards physics material.

In cognitive competencies, the posttest scores obtained by students are in accordance with the value of the learning process they follow. Students who do the steps of discovery models well tend to get good posttest scores. This is evident from the acceptance of the test hypothesis of the relationship between two variables, namely that there is a relationship between the use of Discovery learning assisted by ICT teaching materials and students’ cognitive competencies. The use of Discovery learning can improve students’ cognitive competencies. Discovery activities in learning help students gain meaningful cognitive for students. This is in accordance with what experts say that discovery is a teaching model where the teacher gives students the freedom to find something by themselves because by finding themselves students can better understand it in depth. This means that students not only receive information, but find information through various discovery processes and activities [7].

The results of observations in learning of student activities using Discovery learning are in the form of willingness to follow and be enthusiastic in learning. This is evidenced by the willingness of students to ask questions and answers according to the problems raised and the intertwining of interactions in the practicum group. Students enjoy practicum activities carried out to find concepts. Students are easier to recall the material and concepts they get themselves than the material described by the teacher through the lecture method in previous learning. This is in line with what experts have suggested that the cognitive gained by learning discovery has some goodness, namely: cognitive that lasts long or can be remembered, when compared with the cognitive learned in other ways, the learning outcomes of the invention have a better transfer effect than other learning outcomes [8]. The concepts and principles that belong to one’s cognitive are more easily applied to new situations, and overall learning discovery enhances students’ reasoning and the ability to think freely. Specifically learning discovery trains students’ cognitive skills to find and solve problems without the help of others.
Students’ interest and enthusiasm in the material under study (vector and straight motion) are also caused by the animations and videos contained in ICT teaching materials. Students become more understanding when they can observe and try directly to find concepts. This was also stated that in order to study physics and form cognitive about physics, direct contact with what you want to know is needed. This is why the experimental method where students can observe, measure, collect data, analyze and conclude is very suitable to explore physics [7].

In the application of discovery learning, teachers guide students to learn faster to achieve high-level abilities according to their initial abilities. This is the function of the teacher that has to identify students’ initial abilities before learning begins. Giving problems that will be solved before learning can help the teacher to assess the extent of students’ abilities. During this study, at each meeting, students were given a test before learning began to measure the ability of each student.

The initial cognitive that the student has is then constructed through a process of discovery. The discovery is expected to produce concepts to gain meaningful experience and cognitive. This meaningful and long-lasting cognitive helps students improve their competence as evidenced by increasing student learning outcomes after discovery learning is applied.

In the skills competency, the student’s score increases from each practicum to the next practicum. This is because the practical steps taken for four times tend to be the same, for example on the stopwatch reading indicator. In the second practicum about Regular Change in Straight Motion, only a few students could read the stopwatch correctly, while others were still learning. In the third practicum about free fall motion which also uses a stopwatch, the number of students who can read stopwatches is increasing, and in the fourth practicum about vertical upward motion, all students have been able to read the stopwatch correctly.

The use of Discovery learning helps students build cognitive and skills based on prior cognitive and skills. Students who previously had cognitive of stopwatches were guided to be able to use them directly, and students who were completely unfamiliar with stopwatches were introduced first. This is consistent with one character

4. Conclusion
Based on the results of data analysis and discussion, it can be concluded that: There is an effect that means the use of Discovery learning assisted by ICT teaching materials on the achievement of students’ cognitive competence at a significance level of 0.05.

References
[1] J. e. a. Russell, "Use of Simultaneous-Synchronized Macroscopic, Microscopic, and Symbolic representations to Enhance the Teaching and Learning of Chemical," Journal of Chemical education, vol. 74(3), pp. 330-334., 1997.
[2] Hamidah, "Developing electric field learning media using Finite Element Method Laboratory to enhance the quality of physics learning instruction.," in Preceding of UPI-UPSI International Seminars., Perak-Malaysia., 2008.
[3] I. K. G. D. Putra, "Pendidikan Berbasis Teknologi Informasi," Rakorda Disdikpora Bali, Bali, 2009.
[4] Masril, Hidayati, Darvina Y, "Rancangan Laboratorium Virtual untuk Pembelajaran Fisika SMA.," JURNAL EKSKA Kternikata PENDIDIKAN (JEP), pp. 71-77, 2018. Doi: https://doi.org/10.24036/jep/vol2-iss1/139
[5] M. Farreira, "Intelligent classrooms and smart software: Teaching and learning in today's university", Springer Science and Business Media., Springer publications, 2010.
[6] B. R. Kristy J. Wilson, "Scientific Process Flowchart Assessment (SPFA): A Method for Evaluating Changes in Understanding and Visualization of the Scientific Process in a Multidisciplinary Student Population," CBE Life Sci Educ, vol. 15(4), no. doi: [10.1187/cbe.15-10-0212], 2016.
[7] P. Suparno, Metodologi Pembelajaran Fisika., Yogyakarta:: Universitas Sanata Dharma, 2013.
[8] R. W. Dahar, Teori-Teori Belaja, Jakarta: Erlangga, 1989.
[9] Kemendikbud, "Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia Nomor 53 tahun 2015 tentang Penilaian Hasil Belajar oleh Pendidik pada Pendidikan Dasar dan Menengah," Jakarta, Depdikbud, 2015.

[10] Kemendikbud, "Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia Nomor 59 Tahun 2014 tentang Kurikulum 2013 Sekolah Menengah Atas/ Madrasah Aliya," Jakarta, Depdikbud, 2014.