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A Virtual Lab Activity Combined with a Prediction-Observation-Explanation Model to Improve Students Learning Outcomes in Direct Current Circuit

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Abstract: Laboratory activities are very important in the process of teaching and learning physics in schools. Limited laboratory facilities in schools are enough to hinder direct laboratory activities. The combination of predict-observe-explain (POE) learning with virtual laboratory activities can be an alternative to developing a more active, interesting, and meaningful physics learning process and overcome the limitations of equipment in the laboratory. This study aims to describe virtual lab activities with POE learning on student cognitive learning outcomes in direct current circuit topics. Participants were taken from senior high school students in the 12th grade in Palangka Raya, Indonesia. It includes 30 students who have not yet studied direct current circuits. A pre-experimental research method with a one-group pre and post-test design was used. The finding indicates that students cognitive learning outcomes were increased with a medium category (N-Gain score 0.69). Specifically, the increase was found in the subtopics electric current and potential difference (N-Gain score 0.66), simple direct current circuits (N-Gain score 0.68), electrical circuits series and parallel (N-Gain score 0.73), and Ohm's Law (N-Gain score 0.70). Based on this research, virtual-lab activity with POE learning could be considered an alternative to conducting a meaningful learning activity, especially in physics learning.

Keywords: crocodile physics, direct current, physics, POE learning model, virtual lab.

Abstrak: *Kegiatan laboratorium sangat penting dalam mendukung keberhasilan proses belajar mengajar fisika di sekolah. Namun, keterbatasan fasilitas laboratorium di sekolah cukup menganggu aktivitas-aktivitas laboratorium. Kombinasi antara pembelajaran predict-observe-explain (POE) dengan kegiatan laboratorium virtual dapat menjadi salah satu alternatif untuk mewujudkan proses pembelajaran fisika yang lebih aktif, menarik, dan bermakna serta mengatasi keterbatasan peralatan di laboratorium. Penelitian ini bertujuan untuk mendeskripsikan dampak kegiatan virtual lab dengan pembelajaran POE terhadap hasil belajar peserta didik pada topik rangkaian arus searah. Peserta merupakan peserta didik kelas XII di salah satu SMA di Kota Palangka Raya, yang terdiri dari 30 peserta didik yang belum mempelajari rangkaian arus searah. Penelitian ini merupakan penelitian pra-eksperimen dengan desain one-group pre and post-test. Hasil penelitian menunjukkan bahwa hasil belajar peserta didik meningkat dengan kategori sedang (diperoleh skor N-Gain 0,695). Secara spesifik, peningkatan tersebut ditemukan pada subtopik-subtopik arus dan tegangan listrik, rangkaian listrik sederhana, rangkaian listrik seri dan paralel, dan Hukum Ohm. Berdasarkan penelitian ini, kegiatan virtual lab dengan pembelajaran POE dapat dipertimbangkan sebagai salah satu alternatif untuk melakukan kegiatan pembelajaran yang bermakna, khususnya dalam pembelajaran fisika.*

Kata kunci: *crocodile physics, arus searah, fisika, model pembelajaran POE, lab virtual.*

▪ INTRODUCTION

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Students should be encouraged to actively participate in their learning through experimental works when learning about direct current electric circuits in physics, for example, experiments to determine the characteristics of series resistance circuits or parallel resistance circuits, or experiments to determine the relationship between potential difference and electric current strength using simple electric circuits. It is hoped that by engaging in experiments such as these, students will gain a deeper understanding of the subject matter. According to Urbancic and Glazar (2012), through experimental activities, students should learn how to manipulate variables, make precise observations, and carefully record data as they gather information for understanding concepts and phenomena. Enables students and pupils to take part in science through varying designed practical work, including experimentation, is regularly claimed to support learning and motivation.

Based on the results of an interview, a physics teacher for class XII at a local high school stated that one of the subjects that students have trouble understanding is direct current electric circuits. Marcelina & Hartanto (2021) and Osman (2017) state that the teaching and learning of electricity are always difficult tasks for the teacher and the students. The teacher revealed that this difficulty was caused by many formulas that confused students. The teacher's statement is consistent with the results of interviews with students. Some believe that learning physics is similar as learning to memorize a series of equations or formulas. Many students believe that studying physics requires memorization of formulas and algorithms for solving problems (Sahin, 2009). According to Dorneles et al. (2010), many studies focus on the teaching simple electric circuits, and even after receiving formal instruction, students are unable to understand the behavior of the physical magnitudes used in these circuits. Benckert and Pettersson (2008) found that many high school and college students find studying physics uninteresting, and many do not fully understand the concepts of physics.

Moreover, the student interview results show that students are less interested in physics and less active in the learning process in class. Guido (2013) states that the lack of attitude and motivation towards physics will make it difficult for them to understand the subject of physics more deeply. In the case of the topic of direct current electric circuits, learning is dominated by the delivery of material by the teacher, working on questions, and giving homework. Further interviews revealed that laboratory acitivities were rarely conducted as many of the existing devices were not working properly, particularly on the subject of DC circuits. The results of the Williams et al. (2003) found that students found science laboratory activities very interesting and many students regretted the lack of this type of activity. There are many interesting concepts related to direct current that can be learned through direct experience in the classroom.

As ICT technology has advanced, virtual labs have also emerged as powerful environments. Virtual labs simulate real science labs on a computer screen in a visual and functional way, using modern multimedia technology and in particular user interaction, instantaneous and realistic variable change and device manipulation (Kocijancic and Sullivan 2004). Crocodile Physics software has been chosen as one of the various tools available. By using the program, students can carry out virtual experiments related to electrical subjects based on their interests and designs (Sari et al., 2020). Crocodile Physics permits students to independently or collaboratively perform laboratory tasks and efficiently obtain feedback through computer simulation (Darrah et al., 2014). The Crocodile Physics program offers students the opportunity to carry out virtual experiments on electrical topics based on their designs. Virtual labs, like Crocodile Physics, are more user-friendly and offer better security than physical labs (Ceberio et al., 2016).

According to Kereh et al. (2020), high school students can increase their understanding of physics and get the best learning outcomes by using learning resources based on the simulation software Crocodile Physics. The results of this study are consistent with research conducted by Gumrowi (2016), which showed that physics learning strategies through Crocodile Physics simulations can improve student learning outcomes. According to the study findings by Rodríguez et al. (2021), virtual laboratory, such as Crocodile Physics media, had a positive impact on students' interest in learning. The findings of this study show that students' interest in learning science can be raised by using Crocodile Physics media. Crocodile Physics' virtual simulations have the potential to assist students to perform better in physics classes. Crocodile physics, according to Hamamous & Benjelloun (2022), improves the learning process, inspires students during class, improves student interaction, and raises student participation in the learning process.

Virtual laboratory combined with active learning can deliver better learning outcomes. Ambusaidi et al. (2018) discovered that the development of modern virtual/computer tools tends to achieve active and meaningful learning circumstances. Most of the virtual laboratory technologies employed, including Crocodile Physics, were combined with constructivist teaching techniques, which improved significantly student achievement (Antonio & Castro, 2023). Virtual laboratory technologies that support content-based instruction, which is student-centered, have the most potential to make a positive difference in science teaching and learning (Smetana & Bell, 2012).

One learning model that can enable students to actively participate in learning is the Predict Observe Explain (POE) learning model. In this learning model, students have to predict a phenomenon, observe it through experiments, and explain the suitability of the prediction based on the experimental result (Hartanto et al., 2023). Some research results combining the POE model and the virtual laboratory have a good impact on the achievement of student learning outcomes. The research results of Sari et al. (2020) showed better learning outcomes in virtual laboratory-based POE learning. The same result was also reported by Alfiyanti et al. (2020) concluded that the virtual lab with POE model is effective for improving high school students' understanding. The success of POE is seen as a strategy that takes into account the constructivist approach, which includes reflective teaching processes and active participation, in contrast to the traditional approach that emphasizes teacher dominance (Kibirige et al., 2014).

Based on the description above, this article aims to provide a description of research results on student learning outcomes in virtual laboratory-assisted POE learning models. Specifically, the description of this research relates to the topic of direct current electric circuits.

▪ METHOD

Participants

The population in this study were students of 12th grade MIPA at one of the Senior High schools in Palangka Raya City. The sample was determined by using the purposive sampling technique. The sample class in this study was 12th grade MIPA-2 at a public senior high school in Palangka Raya City with 30 students.

Research Design and Procedures

This research is a pre-experimental study using a one-group pretest-posttest design which gives treatment to the sample class to find out the changes that have occurred. Research using the one-group pretest-posttest design is a study by administering tests before and after being given treatment in the sample class without any comparison group (Creswell, 2014 & Ismail et al., 2019).

On direct current electric circuit material, the sample class was treated by using physics learning with the predict-observe-explain (POE) model assisted by a virtual laboratory using Crocodile Physics. The POE model of learning employs three steps: prediction, observation, and explanation, which are adapted from several relevant research findings (Marcelina et al., 2022; Karamustafaoglu & Mamlok-Naaman, 2015).Based on research conducted by Marcelina et al. (2022), the POE model can increase students' understanding of science concepts. According to Ayvaci (2013), learning using the POE model makes students feel more interested in learning science. Learning by applying the POE model is better than teacher-centered learning (Hilario, 2015).

In addition to POE, Crocodile Physics media was used in this study's treatment. Crocodile Physics is software that is useful for carrying out a simulation that resembles an experiment carried out in a real laboratory as shown in Figure 1. Crocodile Physics is a computer program used to design virtual experiments. One of the reasons this program was chosen for this study was its simplicity of use. According to Hamamous & Benjelloun (2022), Crocodile Physics and similar programs enable users to operate virtual laboratory equipment with symbols and appear like in a physical lab. Users of Crocodile Physics can access symbols and lifelike lab instrument displays. According to Budi et al. (2014), students can create simulation models that will be carried out on their own. Through simulations presented by Crocodile Physics, students are greatly helped to understand physics learning. In this study, crocodile physics was used offline with the help of a computer. Table 1 provides a description of the treatment provided in this study.

Table 1. A description of learning about direct current electric circuits using the POE model and Crocodile Physics

Learning Stages	Learning Activity Description
Stage 1: Predicting	The teacher poses a direct current electrical circuits problem. At this stage, students make predictions about the problems along with explanations for their assumptions
Stage 2: Observe	At this stage, the teacher helps the students carry out virtual experiments, gather data, and perform data analysis to verify the prediction put forth. Crocodile Physics is used to help with this stage. The students were guided by the worksheet that includes instruction guide, template for table and graph, and some questions.

Stage 3: Explain	With their respective groups, students talk about the experimental findings at the observation stage and contrast the findings with earlier prediction.

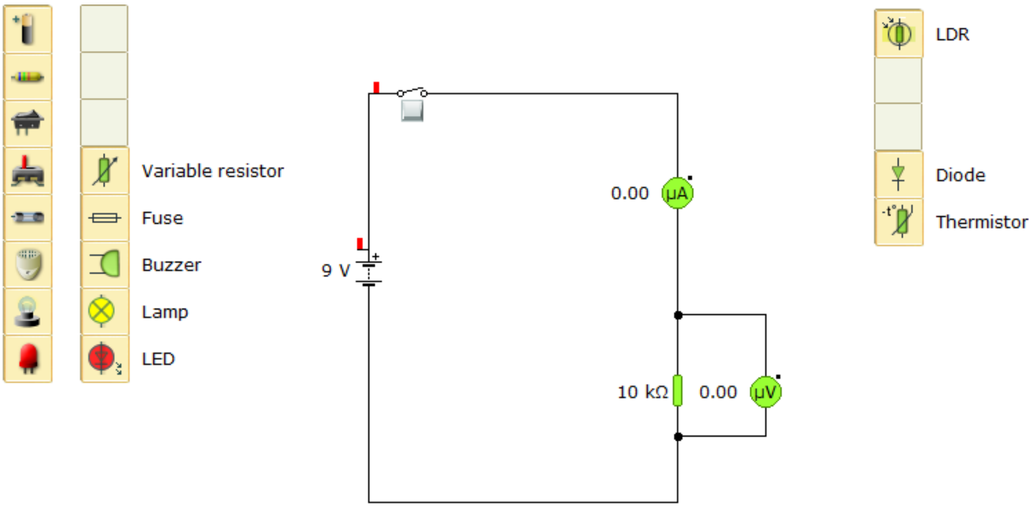


Figure 1. Screenshot example of a direct current electric circuit simulation in crocodile physics

Instruments

The instrument in this study was a multiple-choice test of learning outcomes and consisted of 20 questions. This learning outcomes test includes 5 questions regarding the concepts of electric current and potential difference, 4 questions regarding simple direct current electrical circuits, 6 questions regarding electrical circuits (series, parallel, series, and parallel combinations), and 5 questions regarding Ohm's Law. This test is administered both before and after the learning process (pre-test and post-test). The test instrument was tried out after being validated by the lecturer and several physics teachers before being used. The test instrument's Cronbach alpha value was 0.56.

Data Analysis

To determine whether or not there was a difference in learning outcomes before and after the researcher's treatment, the test results were analyzed using a paired t-test. The researcher first performed a normality test to determine whether or not the data was normally distributed before performing the paired t-test. The category of the test score increase is then determined by calculating the N-gain score. In order to determine the improvement in student's mastery of learning outcomes, the increase in learning outcomes was analyzed using N-gain analysis, specifically by comparing the difference between post-test and pre-test scores with the difference in total scores with the pre-test whose results were multiplied by 100 (Hake, 1999). The criteria listed in Table 2 by Majdi et al. (2018) are used to determine the interpretation of improved cognitive learning outcomes.

Table 2. N-gain learning effectivity interpretation

***Mean* N-gain**	**Students cognitive learning outcomes interpretation**
<g> < 0.3	Low
0.3 ≤ <g> ≤ 0.7	Moderate
<g> > 0.7	High

▪ RESULT AND DISSCUSSION

After the pre-test and post-test were implemented, the data achieved was then analyzed. The answers from 30 students were counted and analyzed to obtain the correct answers. The initial average score of students obtained from the pre-test was 41.11. Meanwhile, the final average score obtained from the final test was 80.44.

After the average score was calculated, the normality test, N-Gain, and nonparametric Wilcoxon signed-rank test were then carried out to further investigate the data more deeply by using SPSS ver. 24. The normality test and the pre-test gets sig. 0.203, and the post-test obtained 0.000. Hence, since the pre-requisite of normally distributed data is sig. value > 0.05, the pre-test is considered distributed as normal, while the post-test was not normally distributed. In spite of this, a nonparametric test was conducted. The hypothesis test, the Wilcoxon signed-rank test, was carried out. Asymp. Sig. (2-tailed) gained was 0.000, which means it suggests that students' learning results were significantly affected after implementing the virtual lab (crocodile physics) since the asymp. Sig. (2-tailed) value is less than 0.05.

Especially for the results of the N-Gain calculations can be seen in Figure 2. The N-Gain score for sub topic electric current and potential difference was 0.66 which was ranked as medium improvement in student cognitive learning outcomes. The same results were also obtained for the sub topic simple direct current circuit and Ohm's law, each obtained an N-Gain score of 0,68 and 0,70 (medium improvement). Whereas for subtopic electrical circuits, it obtained an N-Gain score of 0.73, which is included in the high improvement category. The average N-Gain score was 0.69 which was ranked as medium efficiency in students cognitive learning outcomes.

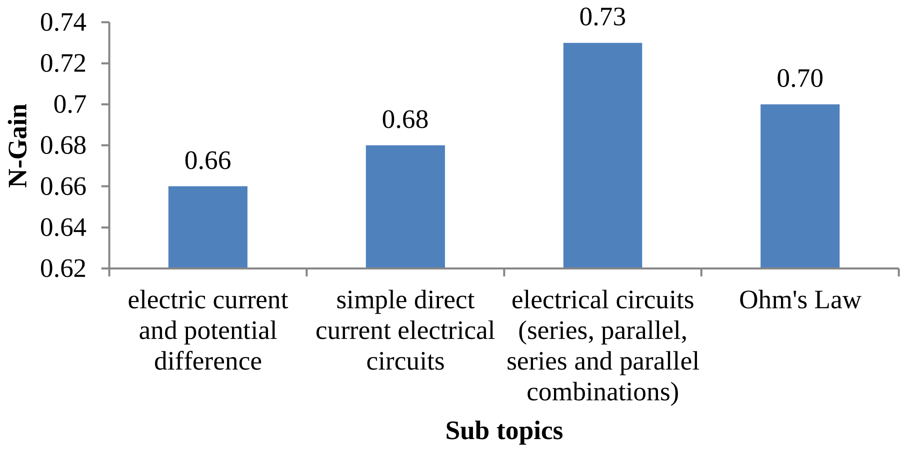
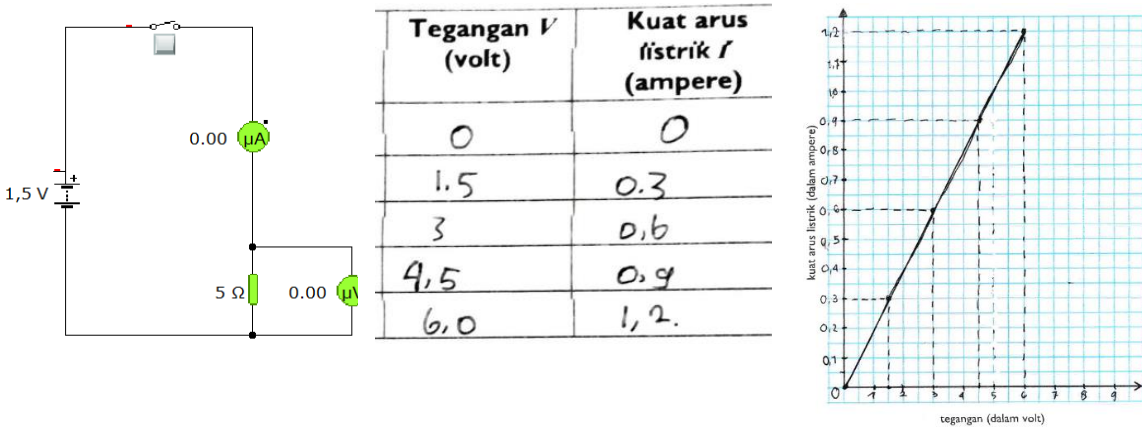


Figure 2. The average N-Gain of several sub-topic

The results of the analysis above indicate that there is an increase in student cognitive learning outcomes related to the topic of direct current electricity. These results were made possible by the use of POE in combination with a virtual lab (crocodile physics). Students learn more actively by making predictions, conducting virtual experiments, and giving explanations based on the outcomes of their experiments to test their predictions. This is fulfilled by using POE and Crocodile Physics. Because students participate in experiments and observe electrical phenomena rather than just listening to their teachers, learning becomes more interactive. Students can compare theory with reality by engaging in empirical observation, increasing their self-belief in the factuality of the learning material (Suryaningsih, 2017; Hartanto, 2017), in the end, have an impact on student understanding. According to Alfiyanti et al. (2020), the POE learning model with virtual laboratory can engage students actively in learning, making it simpler for them to comprehend the material being taught. According to research done by Taqwa and Putra (2017), using the POE model can encourage students to understand the concepts by using a virtual laboratory. Additionally, Hartanto et al. (2023) discovered that students' scores improved both before and after receiving physics instruction using a POE model with the aid of a virtual laboratory.

Researchers also analyzed that the increase in students cognitive learning results was due to students experiencing directly the learning being studied. Students can also prove formulas found in the literature through virtual experimentation using Crocodile Physics simulations. Hartanto (2017) argues that the best way to learn science is to offer students opportunities to gain experience. Qurniawan (2018) argues that the increase in student learning outcomes through learning with the virtual Crocodile Physics lab is due to the learning media providing learning experiences to students. Budi et al. (2014) also stated that the use of Crocodile Physics simulation media gives students an insight into electronic circuits so that they become more understanding.

Crocodile Physics provides experience through virtual experiment activities that are easily carried out by students. Crocodile Physics provides its users with symbols and real-life views of laboratory equipment. Based on the observation during the learning process, students can alter the simulation's variables (such as the resistance in a virtual electrical circuit) using Crocodile Physics, and then watch how those changes affect other variables (such as voltage or current). Students can quickly and easily conduct experiments and gather experimental data thanks to the simulations. Students can investigate the underlying model's properties, such as Ohm's law, by methodically altering variables and then observing and interpreting the results of those changes. Ohm’s law. Dewi et al. (2022) and Sari et al. (2017) stated that users can easily use virtual laboratory equipment with symbols that look similar to their appearance in real laboratories through Crocodile Physics. The experiment using a virtual lab simulation is also more entertaining because this medium comes with simple experiments that make it easier for students to learn and interact with the simulation (Alfiyanti et al., 2020).



Tegangan V (volt)	Kuat arus listrik I (ampere)
0	0
1.5	0.3
3	0,6
4,5	0,9
6,0	1,2.

(a) (b) (c)

Figure 3. An example of student work results on worksheets during learning: (a) circuit with variable V but constant R, (b) table of increasing current for higher voltage, (c) graph of voltage and current values with constant R.

Figure 3 presents an example of student work on worksheets related to Ohm's law when learning with POE and Crocodile Physics simulation. Students use the mouse to drag and drop a resistor, an ammeter, a voltmeter, and a current source onto the workspace and connect all this according to a circuit with wires; they put in a battery and take measurements. Students can see how the current depends on the voltage with a constant resistor. A student obtained a graph while conducting an experiment to study the dependence of current on the potential difference across a resistor. The results of this student's work show that Crocodile Physics can be used easily by students and provide an experimental experience like a real experiment. The virtual laboratory, according to Suryanti et al. (2019), was created as a useful computerized learning tool that can take the place of real laboratories for conducting routine experiments and demonstrations.

Researchers also suppose that these outcomes are also influenced by students' interest in the media used. According to Gunawan et al. (2018), students are more motivated to learn when the learning materials they are using are more engaging. Virtual laboratories are used to draw students' attention, satisfy their interest, and keep them motivated (Hartanto et al., 2023; El Kharki et al., 2021). As a result, students' conceptual understanding of physics is also improved.

The essence of Crocodile Physics-assisted POE learning is that students learn by doing. Hands-on science encourages children to do something through observing, asking questions, experimenting, analyzing, and drawing conclusions. Allowing students to truly immerse themselves in science gives them the opportunity to make their own discoveries. They will tend to remember the learning experience if it is based on real experience (Hartanto, 2017; Suparno, 2007). Furthermore, students can learn scientific processes throughout the lesson.

There is one interesting and important note obtained from this research. Crocodile physics media should be shown to students in advance so that students can use the software in practical activities. Gumrowi (2016) states that one of the things that cause a lack of student learning outcomes is that some students have not been able to understand how to use Crocodile Physics. This shows that the teacher should guide students in using crocodile physics before they learn because this simulation uses English in its functioning. It is necessary to provide advice to students so that they can use the Crocodile Physics software.

▪ CONCLUSION

The implementation of a virtual laboratory (Crocodile Physics) with POE learning on direct current topics was done with a sample that consists of 30 12th grade Senior High School students. After calculating the data, students' learning outcomes were increased by the pre-test score was 41.11, while the post-test was 80.44. The Wilcoxon signed-rank test was implemented. It suggests that students' learning outcomes were significantly affected after implementing Crocodile Physics with POE learning. Furthermore, the average N-Gain score that scored 0.69 indicated a medium improvement in students cognitive learning outcomes. To sum up, the use of Crocodile Physics as a virtual laboratory combined with POE in learning direct current circuit topics shows a favorable result on students cognitive learning outcomes.

With POE learning activities assisted by a virtual laboratory (Crocodile Physics), it is hoped that teachers will be able to equip students with investigative and explorative physics so that they are able to make predictions. Students seek answers to predictions they make through virtual observations and experiments. Next, students provide an explanation of the suitability between the conjecture and the results of their virtual experiment.

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