

## Implementation of NPIVL to Improve Critical Thinking Skills of Pre-Service Physics Teacher

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### Abstract

This study aimed to describe the critical thinking skills of pre-service physics teacher through the implementation of the Nuclear Physics Inquiry Virtual Laboratory (NPIVL) program. This study used a quantitative pre-experimental study with one group pretest-posttest design involving 14 pre-service physics teachers at one of universities in Banjarmasin, South Kalimantan. The research sample was taken using purposive sampling. The instrument used in this study was a test of critical thinking skills with 25 essay type questions. The questions were compiled based on five indicators of critical thinking skills, namely elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. Data were analyzed using quantitative descriptive. Based on the results of the study, it was found that pre-service physics teachers' critical thinking skills had a normalized N-gain of 0.33 in the medium category. The percentage of the increase in critical thinking skills indicators was varied, from the largest were basic support, elementary clarification, inference, advanced clarification, and the smallest was strategy and tactics. Based on these findings it can be concluded that the implementation of the NPIVL program can improve the thinking skills of pre-service physics teacher.

**Keywords:** Critical Thinking Skills; NIPVL; Pre-Service Physics Teacher

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### INTRODUCTION

The public mindset is still dominated by fear of nuclear technology, even though the benefits of this technology have been widely used (Bird et al., 2014). This happens because nuclear is identical to

atomic bombs, danger, radiation, and various other negative effects (Hartini et al., 2021; Roh & Kim, 2017; Stefanelli et al., 2017). Education presents to answer those challenges (Bhanthumnavin & Bhanthumnavin, 2014; Brown, 2018;

Hartini et al., 2021) by using information communication technology of nuclear facilities, through education related to nuclear physics that can be carried out (Syarip et al., 2018).

Various countries have developed nuclear physics education programs to increase students and public knowledge about nuclear physics. Some of these programs include PULSAR reactor research (Malkawi & Al-Araidah, 2013); *Cyber Learning Platform for Nuclear Education and Training* (CLP4NET) (Yakovlev et al., 2015); *Radioactivity Remote Laboratory Activities* (RRLA) (Karpudewan & Chong, 2018). The program is research involving a nuclear reactor centered, students, teachers, communities and academics.

Knowledge of nuclear physics is found in nuclear physics courses. Based on the results of curriculum studies at several universities in Indonesia, there has been no laboratory activity as part of the nuclear physics course because the two activities are separated. There are only some universities that have real laboratory facilities, but the equipment is very limited and expensive. In addition, the practicum in virtual laboratory activities have not trained specific skills such as inquiry skills because practicum activities are still conventional. Based on this, the Nuclear Physics Inquiry Virtual Laboratory (NIPVL) program presents to answer this challenge. In this activity the NIPVL program used the Internet Reactor Laboratory (IRL) Kartini as Virtual Laboratory from Center for Science and Accelerator Technology in National Nuclear Energy Agency of Indonesia.

NIPVL is a practicum activity that develops inquiry skills using virtual laboratory activities. The inquiry practicum model consists of open-ended questions, scientific information, procedures or designs, data analysis and results, communication result and conclusions (Srisawasdi & Kroothkeaw,

2014). The NIPVL program is implemented in two stages; pre-laboratory and laboratory. In the pre-laboratory stage, the inquiry stage that trained are open questions and scientific information. In the inquiry stage of the laboratory stage, the training included procedure or experimental design, data analysis, communication results and conclusions. Activities at the pre-laboratory and laboratory stages involve critical thinking skills as higher-order thinking skills.

In making decisions, critical thinking is the most basic thing (Ennis, 1989). Critical thinking has potential in helping students make good decisions (Yacoubian, 2015). Critical thinking skills are important in higher education (Tiruneh, et al 2017; Tiruneh et al., 2018), the success of critical thinking skills is related to the improvement in decision making on real life problems and being an active citizen (Halpern, 2014).

Based on the background above, a study was conducted on the implementation of the NIPVL program on students' critical thinking skills. The purpose of this study was to describe the critical thinking skills of pre-service physics teacher through the NIPVL program implementation. This study is expected to contribute in preparing high-order thinking skills students, thus they can become active citizens in solving problems leading to society 5.0.

## METHOD

This research is a quantitative pre-experimental study with a one group pretest-posttest design as shown in table 1.

Table 1 *One Group Pre-test-Post-test Research Design*

| <i>Pretest</i> | <i>Treatment</i> | <i>Posttest</i> |
|----------------|------------------|-----------------|
| O <sub>1</sub> | X                | O <sub>2</sub>  |

(Creswell & Guetterman, 2019)

with,

O<sub>1</sub>: pretest score before the NPIVL implementation;

O<sub>2</sub>: posttest score after the implementation of NPIVL; and

X: the implementation of NPIVL

The implementation was carried out to the pre-service physics teachers at one of universities in Banjarmasin, South Kalimantan, totally of 14 students. The pre-service teachers did a pre-test before implementing NPIVL. The NPIVL program is implemented with pre-laboratory and laboratory activities. In this activity students are trained in critical thinking skills by providing student worksheets. Later, the pre-service physics teacher did the post-test. The findings on the pre-test and post-test were used to determine the increase in the critical thinking skills of pre-service physics teacher. The critical thinking skills indicators used refer to the critical thinking indicators from Ennis, namely: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics

The instrument used to collect data in this study was an essay test consisting of 25 questions. The problem solving skill improvement was calculated by normalized gain with the equation (1) (Hake, 1998):

$$\langle g \rangle = \frac{\% \langle G \rangle}{\% \langle G \rangle_{max}} = \frac{(\% \langle s_f \rangle - \% \langle s_i \rangle)}{(100 - \% \langle s_i \rangle)} \quad (1)$$

with:

$\langle g \rangle$  = normalized average gain;

$\langle G \rangle$  = average actual gain;

$\langle G \rangle_{max}$  = average maximum possible gain;

$\langle s_f \rangle$  = average final test score; dan

$\langle s_i \rangle$  = average pre-test score.

Interpretation of  $\langle g \rangle$  is categorized (Hake, 1998) in Table 2.

Table 2 Normalized Gain Value

| Value $\langle g \rangle$          | Classification |
|------------------------------------|----------------|
| $\langle g \rangle \geq 0.7$       | High           |
| $0.7 > \langle g \rangle \geq 0.3$ | Intermediate   |
| $\langle g \rangle < 0.3$          | Low            |

## RESULT AND DISCUSSION

This study aimed to describe the critical thinking skills improvement of pre-service physics teacher through the NPIVL program implementation. This research was conducted by providing 25 essay questions with critical thinking skills indicators, namely elementary clarification, basic support, inference, advanced clarification, strategy, and tactics. Each indicator was represented by five questions. The material used was fission reactions, about fission reactors including reactor power calibration, measurement of neutron flux, control rod calibration, fuel temperature reactivity coefficient and reactor criticality.

The improvement in problem solving skill can be seen based on the normalized gain value. The normalized gain value can be seen in table 3.

Table 3 Normalized Gain Values

| Pretest | Posttest | N-gain | Category |
|---------|----------|--------|----------|
| 6.1     | 37.7     | 0.33   | Medium   |

Based on Table 3, the average post-test score increased when compared to the pre-test score. It can also be seen that the normalized gain value is 0.33 in the medium category. This was inseparable from the implementation of the NPIVL program. The NIPVL program is a lecture program based on inquiry-based practicum stages. The inquiry learning model has a positive impact on the critical thinking skills of pre service teacher (Arsal, 2017; Kwan & Wong, 2015; Thaiposri & Wannapiroon, 2015). This is because learning that involves inquiry provides opportunities for students to solve problems like an inventor and collaborate in teams, carry out critical and creative challenges and develop 21st century skills (Astuti et al., 2018; Beckera et al., 2020; Chang et al., 2020; Srisawasdi & Kroothkeaw, 2014). Apart from being based on inquiry-based practicum stages, the NIPVL program also utilizes information technology such as a virtual laboratory. Learning related to nuclear physics, especially nuclear

science and technology, can be carried out by utilizing information technology and available nuclear facilities (Syarip, et al., 2018). Nuclear physics learning programs, especially about nuclear science and technology based on virtual laboratories, have been developed in various countries in order to increase students and public knowledge about nuclear physics (Malkawi & Al-Araidah, 2013; Karpudewan & Chong, 2018; Karpudewan & Chong, 2018).

Based on Table 3, the average post-test score improved when compared to the pre-test score, but the improvement in critical thinking skills was not optimal because the improvement in each critical thinking skills indicator was not evenly distributed. The variation in the critical thinking skills improvement percentage of pre-service physics teacher can be seen in Table 4.

Table 4 Critical Thinking Skills Achievement Based on Pretest and Posttest

| Indicator of Critical Thinking Skill | Pretest (%) | Posttest (%) | Posttest -Pretest |
|--------------------------------------|-------------|--------------|-------------------|
| Elementary clarification             | 3.40        | 41.71        | 38.31             |
| Basic support                        | 8.6         | 51.43        | 42.83             |
| Inference                            | 4.97        | 19.71        | 14.74             |
| Advanced clarification               | 7.80        | 17.14        | 9.34              |
| Strategy and tactics                 | 3.69        | 10.29        | 6.6               |

Table 4 showed the classification of the critical thinking skills indicators achievement based on pretest and posttest. The percentage of each indicator of critical thinking skills increased compared to the pretest results. In the pretest results. The indicators with the large percentage of critical thinking skills were basic support, advanced clarification, inference, strategy and tactics, and the smallest was elementary clarification. In the posttest results, indicators of critical thinking skills with the largest percentage were basic support,

elementary clarification, inference, advanced clarification, and the smallest was strategy and tactics. There was a difference between results of the pretest and posttest, in the pretest the smallest percentage indicator was elementary clarification. Meanwhile in the posttest, the smallest percentage indicator was strategy and tactics.

Table 4 also shows the increase in the percentage of each indicator of critical thinking skills from the results of the pretest and posttest. The basic support indicator is an indicator of critical thinking skills with the largest increase of 42.83%. Followed by indicators of elementary clarification, inference, advanced clarification. The smallest increase is the strategy and tactics indicator of 6.6%.

The following describes each indicator of critical thinking skills with representatives of student answers Table 4 also showed that the improvement in critical thinking skills on the elementary clarification indicator from the pretest and posttest results was 38.31%. The elementary clarification sub indicators used were focusing questions, asking and answering questions about an explanation. Figure 1 was a representative answer from student on one of the questions for the sub-indicator focusing questions.

**False Statement.** During fluks counting, there was also decay of the formation  $e^{-\lambda t_i}$ , and decay during of counting time  $e^{-\lambda t_c}$

Figure 1 Student's Answer Regarding The Equation for The Foil Counting Activity

Figure 1 was the answer to the foil counting activity equation. The goal was the students were asked to analyse the question, namely that in this equation there was only a decay of  $e^{-\lambda t_d}$  due to delay in counting. A statement was given whether the question is correct and students were asked to give reasons.

There were student representatives who can answer correctly. This showed that the flow of students' thinking in solving questions on these indicators can run well, therefore they could take the right steps in solving the questions presented.

The improvement in critical thinking skills in the basic support indicator on the pretest and posttest results was 42.83% and it was the largest improvement in indicators among all indicators of critical thinking skills measured. Basic support sub-indicators included considering the sources credibility, observing and considering a report on the observation results. Figure 2 was a representative answer from a student on one of the questions for sub-indicators considering the source credibility.

Don't agree. Gold foil wrapped in cadmium only interacts with fast neutrons because cadmium can hold slow neutrons so that the value of the neutron flux in gold foil wrapped in cadmium is smaller than gold foil.

Figure 2 A Student's Answer Regarding The Results of The Neutron Flux Measurement Experiment

Figure 2 was the answer about the experimental results of the neutron flux measurement. The objective was for students to evaluate the experimental results that measure the neutron flux on gold foil and cadmium-coated gold foil. The result was that the neutron flux value of cadmium-coated gold foil was greater than the value of non-coated gold foil neutron flux because cadmium was used as a coating material that can absorb slow neutrons which have  $E < 0.4$  eV so that the neutron flux value of cadmium-coated gold foil was greater than a gold foil. A statement was given whether students agree with the statement and asked to give reasons. There were student representatives who answered correctly. This showed that students can consider the credibility of a source.

The critical thinking skills improvement on the inference indicator

based on the results of the pretest and posttest was 14.74%. The inference sub-indicators used include inducing and considering induction results, making and determining consideration values. Figure 3 was a representative of the answers from students on one of the questions for the sub-indicators namely making and determining the consideration value.

The foil counting activity equation is

$$A_s = \frac{\lambda C}{(1 - e^{-\lambda t_i})(e^{-\lambda(t_d)})(1 - e^{-\lambda t_c})}$$

The two foils have the same specifications for mass, irradiation time, counting interval, but the delay time and number of chopping are different, so  $A_s$  is affected by the delay time and the number of chopping.

For example, foil B delay time is 100 seconds and foil A delay time =  $0.5 \times 100 = 50$  seconds then foil B is 100,000 Cps and the number of pieces of foil A =  $0.5 \times 100,000$  Cps = 50,000 Cps, then:

$$A_s \text{ foil A} = \frac{5.10^4}{(e^{-(50)})} = \frac{5.10^4}{1.93.10^{-22}} = 2,59.10^{26} \text{ disintegrasi}^{-1}$$

$$A_s \text{ foil B} = \frac{1.10^5}{(e^{-(100)})} = \frac{1.10^5}{3,72.10^{-44}} = 2,688.10^{48} \text{ disintegrasi}^{-1}$$

From the results of this analysis, the value of the activity of Foil A is smaller than foil B

Figure 3 Student Answer About The Result of Two Foils Counting Activity

In Figure 3, the student answered about the results of the two foils counting activity. The objective was for students to evaluate questions about two gold foils that was not wrapped in cadmium, namely foil A and B with the same mass specification. Then the two foils were irradiated at the same time and then the foil counting was carried out with the same counting time interval but the delay time of foil A was 0.5 times the delay time of foil B. Students were asked to make conclusions about the value of the two counting activities for the two foils if the number of per second counting foil A

is 0.5 times foil B. There were student representatives who can answer the question correctly. This showed that there were student representatives who make conclusions based on making and determining the consideration value.

The critical thinking skills improvement on the advanced clarification indicator based on the pretest and posttest results was 9.34%. Advanced clarification sub-indicators included defining terms and considering definitions, identifying assumptions. Figure 4 was a representative of the student answer from one of the questions for sub-indicators defining terms and considering definitions.

Know :  $\Delta P = 6.165\%$   
 $P_{\text{linear power meter}} = 100 \text{ kW}$   
 Asked :  $P_{\text{measurement}} = \dots?$   
 Answer :

$$\Delta P = \left| \frac{P_{\text{measurement}} - P_{\text{linear power meter}}}{P_{\text{measurement}}} \right| \times 100\%$$

$$6.165\% = \left| \frac{P_{\text{measurement}} - 100}{P_{\text{measurement}}} \right| \times 100\%$$

$$\frac{6.165\%}{100\%} = \left| \frac{P_{\text{measurement}} - 100}{P_{\text{measurement}}} \right|$$

$$-0.06165 = 1 - \frac{P_{\text{measurement}}}{100}$$

$$-1.06165 = -\frac{P_{\text{measurement}}}{100}$$

$$P_{\text{measurement}} = \frac{1.06165}{100}$$

$$P_{\text{measurement}} = 94.193 \text{ kW}$$

So, the actual power value on the measurement is 94.193 Kw.

Figure 4 Student Answer About The Actual Reactor Power Value

Figure 4 was the answer to the question. The objective was for the students to determine the actual reactor power value based on the definition of the actual reactor power value which is the actual reactor power value for non-stationary conditions is ideally the same as the value of the reactor power meter. If there is a difference in the value, it can be determined based on the presentation value of the reactor power deviation. Then students were asked to determine the actual reactor power value if a reactor

had a power deviation of 6.165% and the power value shown by the power meter was 100 kW. There were student representatives who can answer the question correctly. This showed that the student can provide further explanation based on the definition of terms and consider definitions.

The critical thinking skills improvement in the strategy and tactics indicator based on the pretest and posttest results was 6.6% and it was the smallest improvement among all indicators of critical thinking skills that were measured. The strategy and tactics sub-indicator were determining action. Figure 5 was the representative of the student answers from one of the questions for sub-indicators determining action.

The first step is if there is a difference in the value between the measurement results and the power meter channel, then the presentation value of the reactor power deviation must be determined, namely:

$$\Delta P = \left| \frac{P_{\text{measurement}} - P_{\text{linear power meter}}}{P_{\text{measurement}}} \right| \times 100\%$$

$$\Delta P = \left| \frac{96.718 - 100}{96.718} \right| \times 100\%$$

$$\Delta P = \left| \frac{-3.282}{96.718} \right| \times 100\%$$

$$\Delta P = |-0.0339337| \times 100\%$$

$$\Delta P = 3.39\%$$

There is a reactor power deviation of 3.39% from the power meter channel.

The second step: reactor power deviation of 3.39% is still within safe limits, which is below 10%. If the results of the calculation of the percentage deviation of the reactor power are above 10%, then the reactor power calibration must be carried out immediately.

Figure 5 Student Answer on How to Overcome Differences in The Results of Reactor Power Measurements

Figure 5 was the answer to how to overcome differences in the results of reactor power measurement. The objective was for students to design

method to overcome differences in reactor power values obtained from measurements. Students were asked to design a method if in a reactor power calibration, the results of a reactor power measurement were 96.718 kW, but the reactor power value shown by the power meter channel was 100 kW. Only one student can answer the question correctly. This showed that this student can use strategies and tactics in determining actions.

Based on the study result, there were variations in the percentage of each critical thinking skill indicator of the pre-service physics teachers. The larger percentage of critical thinking skills were basic support, elementary clarification, inference, advanced clarification, and the smallest percentage were strategy and tactics. Based on this, in implementing the NPIVL program, more intensive training is needed to train critical thinking skills in the indicators of inference, advanced clarification, and strategy and tactics. In line with (S; Hartini & Liliyasi, 2020) who stated that critical thinking skills require training because they are not innate skills so that a person can be analytical, systematic, fair and open-minded in acquiring knowledge. The stage of NPIVL that trained these thinking skills are at the inquiry practicum stage, namely (1) experimental procedure or design: students formulate practicum steps and design appropriate data tables then collect data using pre-made practicum steps and organize data in data table; (2) data analysis: students perform data analysis; (3) communication of results: students carry out explanation activities; and (4) conclusion: draw conclusions based on the practicum results. In line with some research, inquiry-based learning can stimulate students thinking skills (Arsal, 2017; Kwan & Wong, 2015; Thaiposri & Wannapiroon, 2015). This is important because critical thinking skills are important thinking skills to be

developed in higher education (Tiruneh et al., 2017, 2018) and become a provision of skills in the 21st century (Sinaga et al., 2022).

## CONCLUSION

Based on the research results, pre-service physics teachers' critical thinking skills had a normalized N-gain of 0.33 in the medium category. The improvement percentage in critical thinking skills indicators varied. The basic support indicator is an indicator of critical thinking skills with the largest increase of 42.83%. Followed by indicators of elementary clarification, inference, advanced clarification. The smallest increase is the strategy and tactics indicator of 6.6%. Based on these findings it can be concluded that the implementation of the NPIVL program can improve the thinking skills of preservice physics teacher students.

The limitation of this research is that this research was conducted in limited trials. The material used was in fission reactions. Suggestion for further research, it can be carried out in broader research and tested for other higher-order thinking skills.

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