An investigation of critical thinking skill of pre-service physics teacher in the case of fission and fusion reactions

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Abstract. This study aimed to examine the critical thinking skills of pre-service physics teacher in the case of fission and fusion reactions. This research used quantitative descriptive method involving 22 final-year pre-service physics teacher in one of Institute of Teachers Training in Banjarmasin, South Kalimantan. The instrument used in this study was a critical thinking skill test with essay question types based on five indicators of critical thinking skill by Ennis. The results showed that the critical thinking skills of pre-service physics teacher students on the five indicators were categorized as very low. An improvement is needed in lecturing activities to improve students' critical thinking skills by using experimental activities through a digital environment.

1. Introduction

One of the 21st century skills that is important to be provided to students is critical thinking skills [1], [2]. Critical thinking is the most fundamental achievement in making decisions [3] and has some potentials in helping students make good decisions [4]. Critical thinking involves the ability to make valid conclusions and complex problems solving [5].

Critical thinking is one of the high-level conceptual thinking processes [6]. Developing critical thinking skills is important in higher education [7], [8]. Success in mastering critical thinking skill in higher education is associated with success in improving decision making related to complex real life problems, become more active and knowledgeable citizens [5].

Some research in Indonesia shows that critical thinking skills of physics students are still low. The result of research conducted [9] showed that critical thinking skills of students in the case of geometry optics is very low (24.29). The research showed that students’ thinking skills in the case of kinematics is in low category [10]. Students’ low category in critical thinking skills is caused by several factors. Students’ critical thinking skills is difficult to develop because the learning is still in traditional method.
Critical thinking is considered difficult to be applied in classroom because of; lack of practice, lack of information, and time constraints. Thus it is problematic to integrate critical thinking skills [12].

One branch of physics that is difficult for physics students to understand is nuclear physics. One topic in nuclear physics that is very useful especially in source for the production of electrical energy in the last few decades is fission and fusion reactions. This matter was given after radioactivity material [13]. Nuclear physics are abstract and complex material, the practicum activities require sophisticated equipment, but expensive and difficult in maintaining [14]–[16].

Based on above problems, it is necessary to do further research in order to examine the critical thinking skills of students in the field of physics, especially in the nuclear physics field. The purpose of this study is to examine the thinking ability of students in the case of fission and fusion reactions. Through this research, it is expected to obtain an overview of students of pre-service physics teacher critical thinking skills so that improvements can be made. Thus, students of pre-service physics teacher will contribute as active citizens in solving problems.

2. Methods
The method used in this research is a descriptive quantitative study. The research involved 22 final year pre-service physics teacher students at one of Institute of Teachers Training in Banjarmasin, South Kalimantan. The instrument used was a critical thinking skills test with essay-type questions integrated to fission and fusion nuclear reaction. The test used indicators of critical thinking skills according to Ennis; elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. The validity of the five test items is valid category and the reliability of the test items is reliable. Data were analyzed using percentage techniques and described. The results of the value of critical thinking skills are interpreted in the form of categories by [17].

3. Result and Discussion
The results of the critical thinking skills test for students of pre-service physics teacher in the case of fission and fusion reactions can be seen in table 1. The result of pre-service physics teacher critical thinking skill test showed that are very low. The pre-service physics teacher’s critical thinking skill on each indicator is presented in table 2, 3, 4, 5 and 6.

| Table 1. Result of critical thinking skill test |
|-----------------------------------------------|
| Indicators                  | Mean  | Category |
|----------------------------|-------|----------|
| Elementary clarification   | 40.23 | Very low |
| Basic support              | 41.82 | Very low |
| Inference                  | 41.59 | Very low |
| Advanced clarification     | 41.14 | Very low |
| Strategy and tactics       | 32.95 | Very low |

Profile of the students’ skill on the elementary clarification indicators of the students are shown in table 2. The elementary clarification indicator that used is to focus the question, ask and answer about an explanation. The test of this indicator presents problems regarding fusion reactions. Students are asked to formulate problems based on pictures about fusion reactions in deuterium and tritium and answer questions about the fusion reactions. The results showed that only 9.00% of students reached very high category and 68.00% of students reached very low category. Students’ flow of thinking in making questions is not good. Though the skills of formulating a problem is very important so that students can take the right steps in solving problems. Furthermore, this has an impact on students that they are not able to explain precisely the process of the fusion reaction occurring in deuterium and tritium, which produces *He and neutrons and releases energy of 17.59 MeV.
Table 2. Profile of elementary clarification skills

| Category     | Percentage |
|--------------|------------|
| Very high    | 9.00       |
| High         | 14.00      |
| Intermediate | 0.00       |
| Low          | 9.00       |
| Very low     | 68.00      |

Profile of the students’ skill on the basic support indicator of pre-service physics teacher are shown in table 3. Basic support indicator includes considering the credibility of the source, observing and considering an observation report. The questions in this test present about the formation of the nuclear transmutation. Students are expected to be able to describe what happens when the target nucleus $^{238}\text{U}_{92}$ is shot with a particle so that it becomes an isotope $^{234}\text{Pa}_{91}$. In this indicator 18.18% of students reached very high category and 63.64% of students reached very low category. Students are not able to represent the nuclear transmutation forming process into a new atoms or isotope.

Table 3. Profile of basic support skills

| Category      | Percentage |
|---------------|------------|
| Very high     | 18.18      |
| High          | 0.00       |
| Intermediate  | 0.00       |
| Low           | 18.18      |
| Very low      | 63.64      |

Profile of the students’ skill on inference indicator can be seen in table 4. Inference includes inducing and considering the results of induction, making and determining the value of consideration. The questions presented in this test are about the application of fission and fusion reactions to the nuclear power plant. Students are expected to be able to conclude a nuclear power plants that supports sustainability and carbon-free development. 63.64% of students are unable to elaborate the differences between fission and fission reactors, so they are unable to conclude the nuclear power plant that can support sustainability and carbon-free development.

Table 4. Profile of inference skill

| Category  | Percentage |
|-----------|------------|
| Very high | 18.18      |
| High      | 0.00       |
| Intermediate | 0.00     |
| Low       | 18.18      |
| Very low  | 63.64      |

Profile of the students’ skill on the advanced clarification indicator are shown in table 5. Advanced clarification includes defining terms and considering definitions, identifying assumptions. The questions presented in this test are about the Tokamak fusion reactor. Students are expected to be able to explain the parts of the Tokamak fusion reactor. In this indicator there are no students who are categorized as very high and high. 55% of students were unable to provide further explanation on the function of Tokamak reactor parts such as poloidal magnetic fields, toroidal magnetic fields, coils and plasma.
Table 5. Profile of advanced clarification skill

| Category       | Percentage |
|----------------|------------|
| Very High      | 0.00       |
| High           | 0.00       |
| Intermediate   | 45.00      |
| Low            | 0.00       |
| Very Low       | 55.00      |

Profile of students’ strategy and tactic skills indicator are shown in Table 6. The indicator of strategy and tactic is to determine action. The question presented in this test is about the energy produced from the fusion reaction. Students are expected to be able to use the right strategy in analyzing the amount of energy generated from fusion reactions. 63.64% of students are unable to use strategies to analyze the required energy. There are students who do not write down quantities that they know. There are students who give calculations with correct mathematical equations $Q = \{(4 \, m_{\text{H}}) - (m_{\text{He}}) + 2 \, m_e\} \times 931$ MeV/sma, but they are wrong when determining the amount of energy released when 1 kg of hydrogen is used.

Table 6. Profile of strategy and tactic skills

| Category       | Percentage |
|----------------|------------|
| Very High      | 0.00       |
| High           | 0.00       |
| Intermediate   | 18.18      |
| Low            | 18.18      |
| Very Low       | 63.64      |

The critical thinking skills of final year pre-service physics teacher are very low. Students' critical thinking skills are still low due to traditional learning, lack of training and time to practice critical thinking skills [11]. Critical thinking is considered difficult to apply in classroom because of lack of practice, lack of information, and lack of time, thus it is problematic to integrate critical thinking skills [12].

Critical thinking skills are not an innate ability. Therefore, students need training to be analytically systematic, fair, and open-minded in gaining knowledge. In accordance to opinions that critical thinking is an important aspect that must be developed in higher education [7], [8].

In improving students' thinking skills, enhancements in the lecturing process are needed. Research showed that critical thinking skills can be stimulated through experimental activities [18]. In addition, several studies showed that inquiry-based learning has a positive effect on the critical thinking disposition of pre-service physics teacher [19]–[22]. Students' critical thinking skills can be improved through the learning techniques of Digital Behaviour Change Intervention [23]. Considering nuclear physics material is abstract and complex, and the real practicum equipments that are expensive, and difficulty in material purchase permits, lecture improvement can be done through experimental activities through the digital environment. It is hoped that these improvements can improve students' thinking skill, so that they are equipped to deal with the 21st century and participate in problem solving.

4. Conclusion
The critical thinking skills of pre-service physics teacher in the case of fission and fusion reactions on five indicators were categorized as very low. Therefore, it is necessary to improve lecture that can improve critical thinking skills. One of them is by using experimental activities through a digital environment.
5. References

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