Investigation in the introductory nuclear physics course for pre-service physics teachers

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Abstract. Introductory Nuclear Physics course is found in the curriculum of pre-service physics teachers in the Institute of Teachers Training at South Borneo. This research is carried out to describe the implementation of the course, the perceptions and knowledge of nuclear physics for pre-service physics teachers. This research used a descriptive quantitative method. The research sample used purposive sampling which consist of 42 students on eighth semester and one lecturer of the course. Data was collected through documentation techniques, questionnaires, interviews and observations. The results of the investigation showed that: (1) the course process was not interesting enough by the dominant lecture method of the course and teaching materials written by lecturers without using the latest research results; (2) pre-service physics teachers tend to have negative perceptions and their knowledge were only limited to the knowledge contained in teaching materials written by the lecturer. Therefore, improvements are needed in the course process to answer the challenges of negative nuclear effects through the Education for Sustainability Development (ESD) approach and utilize the latest research results.

1. Introduction
The study of nuclear physics has had a broad impact on society. Nuclear technology has been widely used in research and industrial materials. Some examples include neutron radiography or non-destructive testing through computerized tomography and the production of dense microchips by ion implantation. In addition, the application is also found in material analysis for semiconductor manufacturing, catalysis, and surface analysis. The particle beam from a research accelerator is used to analyze the damage of microelectronic circuits caused by natural radioactivity or cosmic radiation. The technique of ultra-sensitive accelerator mass spectrometry plays a role in improving environmental research, stratospheric ozone depletion, providing data for climate change studies, air monitoring and water quality, and global air and water circulation patterns.

The currently available nuclear fission reactor application is around 17 percent of world electricity, thus reducing CO₂ and other pollutant releases. In a long term, thermonuclear fusion is expected to be a supply of unlimited clean energy. Nuclear engineering has an impact on other forms of energy, including exploration and utilization of oil reserves. In addition, nuclear engineering are used in the fields of medicine and biology. Radioactive isotopes produced by accelerators or nuclear reactors are widely used for treatment and diagnosis and in biomedical research.
Although the use of nuclear technology is now apparent, the mindset of the people is still dominated by the fear of taking risks [1]. Nuclear is often synonymous with danger, pollution, atomic bombs, and other negative things [2–6]. The emergence of challenges to negative nuclear effects can be answered through the concept of sustainable development. Sustainable development is very important to be implemented; therefore development runs well without overriding environmental interests. Education is a means of introducing this concept, of course, as an effort to change people's perspectives, attitudes, and habits towards the environment [7]. Education for sustainability Development (ESD) must be able to produce students who can contribute to problem-solving and sustainable development in the future [8,9]. Therefore, education related to nuclear physics in the concept of ESD is very important not only in the science and engineering domains of disciplines but also for non-scientists. An understanding of nuclear physics in relation to the world around helps to prepare communities to participate in critical discussions in various fields such as energy policy, environmental protection, and national security [10].

Education related to nuclear physics is found in the curriculum of pre-service physics teachers at the institute of teacher training (LPTK) in Indonesia. In one of the LPTKs in Indonesia, the subjects related to the nuclear introduction and their understanding are found in the seventh semester, especially in the Introductory Nuclear Physics course (ABKC 402, 2 SKS). After completing this course students are expected to have broader knowledge and insights about the nuclear structure, nuclear properties, nuclear force and model, binding energy, natural radioactivity, alpha decay, beta decay, gamma decay, nuclear reactions, and fusion and fission, which in turn can be a provision to understand further course material and supplies in the life to come in participating in solving problems in various ways.

Equipping students to participate in solving problems is through thinking skills. Thinking skills are grouped into basic thinking skills and high-level thinking skills. Basic thinking skills include qualifications, classification, variable relations, transformation, and causal relationships [11]. High-level thinking skills include critical thinking, creative thinking, problem-solving, and decision making. Among the four high-level thinking patterns, critical thinking underlies three other patterns of thinking. Critical thinking is called reflective thinking, which is an active, persistent, and careful consideration of a belief or form of knowledge that is taken for granted in terms of the reasons that support it and further conclusions that become its tendency [12]. Besides developing critical thinking related to the cognitive domain, Norris and Ennis also develop dispositions that are critical souls. Disposition of critical thinking in a form of rational thinking, reflecting, focusing on deciding what to believe or do consist of three main processes: the process of problem-solving, reasoning, and the process of producing a number of conclusions through induction, deduction, and value [13].

Critical thinking is a mental habit that requires students to think about student thinking and about improving the process. Therefore, critical thinking is a product of education and training. Some research results show that learning experiences that focus on critical thinking skills can improve students' critical thinking skills [12,14,15]. Based on the background above, it is necessary to conduct an investigation of nuclear physics in the Introductory Nuclear Physics course that associated with the concept of ESD in order to enhance students’ critical thinking skills. The skills can contribute to solve problems and sustainable development nuclear physics in the future.

2. Methods
This research is a quantitative descriptive research. The study was conducted in the even semester of the 2018/2019 academic year. The research sample used was purposive sampling, which consisted of 42 students in eighth semester and one lecturer in Introductory Nuclear Physics course at LPTK in South Borneo, Indonesia. Data was collected through documentation techniques, questionnaires, interviews, and observations.
3. Result and Discussion

3.1. Investigation on the process of introductory nuclear physics course

Introductory Nuclear Physics course in South Kalimantan consists of two classes with the same lecturer. Courses are carried out in accordance with the course contract, which is carried out in 16 meetings consisting of 14 face-to-face meetings, mid semester exam, and final semester exam. The course material presented is nuclear structure, nuclear properties, nuclear force and model, binding energy, natural radioactivity, alpha decay, beta decay, gamma decay, nuclear reactions, and fusion and fission. Table 1 presents the results of the Introductory Nuclear Physics course investigation through questionnaires, interviews, and observations.

| Indicator                  | Investigation Result                                                                                           |
|----------------------------|---------------------------------------------------------------------------------------------------------------|
| Course contract            | In accordance with the course contract                                                                        |
| Course method              | Learning methods used are lectures, discussions, question and answer, problem-solving, and assignments. The most dominant is lecture at each meeting. There are several percentages of student meetings |
| Media and learning technology | Learning media used are blackboard and power point presentation. E-learning is used to upload lesson plan, teaching material, and assignments. |
| Learning Resources         | Learning resources are obtained from teaching materials written by lecturers, books in the library, and the internet. Learning resources from teaching materials from lecturers are less attractive and have not trained thinking skills |
| Assessment and feedback    | Assessment according to course contracts: tasks (attendance, activeness, quizzes, and assignments), mid semester exams and final semester exams. Forms of Assessment: tests (Essay) and Non-tests (Observations). Feedback is done on assignments |
| The use of the latest research results | The results of the latest research are rarely used                                                              |

Based on the results of the investigation, improvements are needed to be made to the course process. The dominant lecture method of courses and the results of the latest research are rarely used. This causes the course to be non-contextual to the problems that occur in society. In addition, learning resources written by lecturers are not very interesting. The problems that arise in the course process have not been able to facilitate students in developing thinking skills, especially critical thinking skills. Some research results show that learning experiences that focus on critical thinking skills can improve students' critical thinking skills [12,14,15].

In addition, lectures also do not reflect the ESD. ESD has the characteristic of creating awareness, containing local and global vision, learning to be responsible, learning to change, participation, lifelong learning, critical thinking, emphasizing systemic approaches and complex understanding, decision making, interdisciplinary, problem solving and satisfying with current needs without sacrificing future generations [7]. There are three perspectives in ESD, which are the main pillars, namely social culture, environment, and economy. ESD can be achieved through lectures that cover issues in real life. Through ESD, students can be born to contribute in solving problems and sustainable development in the future [8,9].

3.2. Investigation on the pre-service physics teachers’ perception and knowledge

Investigation on Pre-service Physics Teachers’ knowledge was carried out through questionnaires consisting of seven indicators, namely indicators knowledge of nuclear binding energy, nuclear models, radioactivity, use of nuclear technology in Indonesia, use of nuclear technology in genetic
engineering in agriculture, use of nuclear technology in animal science, and use nuclear technology in the health sector. The results of the questionnaire can be seen in Table 2.

**Table 2. Pre-service physics teachers’ knowledge**

| Indicator                                              | Percentage |
|--------------------------------------------------------|------------|
|                                                       | Yes | Neutral | No  |
| Knowledge of nuclear binding energy                    | 42  | 42      | 16  |
| Knowledge of nuclear models                            | 84  | 16      | 0   |
| Knowledge of radioactivity                             | 52  | 26      | 22  |
| Knowledge of nuclear technology in Indonesia           | 63  | 23      | 14  |
| Knowledge of nuclear technology for genetic engineering in agriculture | 45  | 23      | 14  |
| Nuclear technology in the field of animal science      | 3   | 58      | 39  |
| Knowledge of nuclear technology in the health sector   | 57  | 42      | 1   |

Based on the results of the questionnaire in Table 2, the tendency of pre-service physics teachers to have the knowledge in teaching materials written by lecturers as in this indicator is the nuclear binding energy, nuclear model, radioactivity, and nuclear technology in Indonesia. For knowledge obtained if pre-service physics teachers search for learning resources from the results of the latest research tend to be low and do not take attitudes such as knowledge of nuclear technology for genetic engineering in agriculture, knowledge of nuclear technology in the field of animal science, and knowledge of nuclear technology in the health field.

Investigation in pre-service physics teachers’ perception was carried out through questionnaires consisting of two indicators, namely indicators perceptions of nuclear technology, and perceptions about the application of nuclear technology to energy in Indonesia. The results of the questionnaire can be seen in Table 3.

**Table 3. Pre-service physics teachers’ perception**

| Indicator                                              | Percentage |
|--------------------------------------------------------|------------|
|                                                       | Yes | Neutral | No  |
| Perception of nuclear technology                       | 34  | 31      | 35  |
| Perception of the application of nuclear technology for energy in Indonesia | 27  | 46      | 27  |

Based on the results of the questionnaire in Table 3, pre-service physics teachers tend to have negative perceptions of the indicators of nuclear technology and nuclear technology in Indonesia. Although pre-service physics teachers have acquired nuclear knowledge in lectures, negative perceptions are more dominant, especially when connected with bombs, environmental pollution, explosive and dangerous fuels. Most pre-service physics teachers do not express their attitude towards the development of nuclear technology for nuclear power plants or in other technologies. Pre-service physics teachers doubt whether Indonesia is ready to build a Nuclear Power Plant both in terms of Human Resources and the location of Indonesia in areas prone to disasters.

The results of the questionnaire in table 2 and 3 indicate that, pre-service physics teachers’ thinking skills need to be developed. Thinking skills can help a person understand how someone sees himself, how to look at the world, and how someone relates to others. According to Dewey [12], Norris and Ennis [13] state that through thinking skills, one can analyze his own thoughts to ensure that someone has made a choice and draw conclusions appropriately. On the contrary, people who do not have thinking skills cannot decide what to think about, what to believe, what decisions need to be
taken, and how they must act. In the end, people who don't have thinking skills will adopt beliefs and passively accept other people's opinions without first considering.

4. Conclusion
Based on the results of the investigation on the Introductory Nuclear Physics course process as well as the pre-service physics teachers’ knowledge and perceptions, the lecture is not enough just by the dominant lecture method of the course and teaching materials written by the lecturer without utilizing the results of the latest research. Therefore, improvement is needed in the courses process through the ESD approach by utilizing issues on the results of the latest research. It is expected that through the improvement of the course process, pre-service teachers can develop critical thinking skills so that they can contribute to solving problems and developing sustainable development in the future.

5. References
[1] Bird D K, Haynes K, Honer R V D, Aneney J Mc and Poortinga W 2014 Nuclear power in australia: a comparative analysis of public opinion regarding climate change and the Fukushima disaster. Energy Policy 65 pp 644-653
[2] Mah D N Hills P and Tao J 2014 Risk perception, trust, and public engagement in nuclear decision-making in Hongkong. Energy Policy 73 pp 368-390
[3] Yuan X, Zuo J, Ma R and Wang Y 2015 How would social acceptance affect nuclear power development? A study from China Energy Research & Social Science 163 pp 179-186
[4] Sun C, Zhu X and Meng X 2014 Post-Fukushima public acceptance on resuming the nuclear power program in China Renewable and Sustainable Energy Reviews 62 pp 685-694
[5] Roh S and Kim D 2017 Effect of fukushima accident on public acceptance of nuclear energy (fukushima accident and nuclear public acceptance Energy Sources, Part B: Economics, Planning, and Policy 12 pp 559-564
[6] Stefanelli R Seidl and Siegrist M 2017 The discursive politics of nuclear waste: rethinking participatory approaches and public perceptions over nuclear waste storage repositories in Switzerland Energy Research & Social Science 34 pp 72-81
[7] Selby D and Kagawa F 2013 Climate change in the classroom: UNESCO course for secondary teachers on climate change education for sustainable development (Paris: UNESCO)
[8] Evans N S Stevenson R B Lasen M Ferreira J A and Davis J 2017 Approaches to embedding sustainability in teacher education: a synthesis of the literature Teaching and Teacher Education 63 pp 405-417
[9] Feinstein N W and Kirchgater K L 2015 Sustainability in science education? How the next generation science standards approach sustainability and why it matters. Science Education. 99 pp 121-144
[10] OECD 2015 PISA 2015 Assessment and analytical framework: science, reading, mathematics, financial literacy, and collaborative problem solving (revised edition) (Paris: OECD Publishing)
[11] Costa A L 1985 Developing minds: a resource book for teaching thinking (Revised Edition, Volume 1) (Virginia: ASCD)
[12] Arsal Z 2017 The impact of inquiry-based learning on the critical thinking dispositions of pre-service science teachers. International Journal of Science Education 37 pp 1326-1338
[13] Yacoubian H A 2015 A Framework for guiding future citizens to think critically about nature of science and socioscientific issues Canadian Journal of Science, Mathematics, and Technology Education 15 pp 248–260
[14] Vieira R M and Vieira C T 2014 Fostering scientific literacy and critical thinking in elementary science education Int. J of Sci. And Math Edu 14 pp 659–680
[15] Tiruneh D T, Cock M D, Weldeslassie A G, Elen J and Janssen R 2016 Measuring critical thinking in physics: development and validation of a critical thinking test in electricity and magnetism Int J of Sci and Math Educ 15 pp 663-682