Fostering Prospective Physics Teachers’ Creativity in Analysing Education for Sustainable Development Based Curricula

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Abstract. This study describes how to foster the creativity of prospective physics teachers in analysing ESD-based curriculum and describing the profile of prospective physics teachers’ work as a form of ESD-based curriculum analysis. This study was a qualitative descriptive study using qualitative observation by observing behaviour consisting of independence, integration, motivations, judgment, flexibility, evaluation, questions, opportunity, and frustrations. Then, questionnaire gave to explore more about the attitude about analysis curriculum based on ESD. Besides the work of the prospective teacher in the form of the results of curriculum analysis was assessed based on the four basic components of the curriculum, namely objectives, content, the learning process designed, and the assessment design. To foster the creativity of a prospective teacher to produce an ESD-based curriculum analysis, all of them can make an analysis based on the basic component of the curriculum but still weak in integrating global issues of SDGs and provide solutions to the problems studied.

1. Introduction

In 2015, the United Nations General Assembly set the Sustainable Development Goals (SDGs) that collected 17 global goals for the year 2030 [1]. To achieve these global goals, a curriculum based on sustainable development is needed in quality education, in this case, education leads to issues for solving global problems in the SDGs. Efforts to encourage people to constructively and creatively face global challenges along with creating resilient and sustainable communities can be pursued through education for sustainable development or called ESD [2]. ESD contains main issues related to sustainable development in teaching and learning; for example, climate change, disaster risk reduction, biodiversity, poverty reduction, and sustainable consumption [3]. Through these main issues, ESD is believed to ensure that all people obtain knowledge, values, and skills for a better life and society [4-5] as well as helping students to reduce the gap between local and global problems [6-7].

ESD is more focused on developing the attitudes and skills owned by communities to deal with regional and global issues related to environmental aspects through education [8] and able to make easy life as well as finding relevant solutions upon the issues [9]. Although it has been introduced by UNESCO since 2005, this program is less concerned seriously related to the development of science education programs in higher education [10]. Therefore, educators must be able to apply ESD-based learning.

ESD does not rule out the possibility to be applied in learning physics, as one a branch of science. To implement ESD-based learning, it is necessary to analyse the curriculum so that ESD-based learning can be designed. Also, educators must have creativity in designing and managing the learning process so that they can infiltrate certain physical material with sustainable development main issues, this is one
of the major problems for higher education educators [11]. Sustainable development in higher education involves a vibrant and holistic manner of learning [11]. Learning physics at the secondary level does not fully contain the ESD-based curriculum framework so that the hope of realizing a resilient and sustainable society still cannot be implemented. Physics learning still refers to textbooks and textual problem solving with case studies that have not oriented to global issues or attain experimental activities on a laboratory scale [12], not yet reaching the realm of finding solutions to global problems that are now happening on earth. Brundiers analyses how important sustainability competencies are, such as problem-solving skills and the ability to work with experts and stakeholders which need to be acquired in real-world learning opportunities [13].

Creative thinking is a rapidly growing worldwide community trend that promotes sustainable development projects, value chains, and supply chain relationship management [14]. Therefore, efforts need to be made to foster the creativity of prospective physics teachers in the analysis of ESD based curricula to support the SDGs program. To carry out this goal, a research subject with a high level of thinking ability is required and has a good academic background. In Mathematics and Natural Sciences Faculty of Surabaya State University (Universitas Negeri Surabaya), in which the research conducted, distinguished class program, which is selected through academic achievement indexes, English language proficiency and ability fields through interviews and written tests, is chosen to be the subject of the research to foster creativity in compiling an ESD based curriculum analysis.

Creativity education and environmental education are significant fields of studies but stay distant, with little efforts being made to bring them closer together [15]. The nature of the connection between organizational creativity and sustainability, however, is frequently ignored [16]. Creativity can be a critical element of addressing environmental sustainability and a widespread framework is provided [17]. It is a significant catalyst for both learning products and services to be innovative [16]. By applying new thoughts, it plays a significant role in enhancing learning processes and learning product designs [14]. Lozano claims that creativity and organizational learning can help defy traditional Newtonian and Cartesian mental models while promoting more sustainable societies [18].

The role of creative skills within the limits of green technology and sustainable development has so far received very little attention [14]. Although creativity as a problem-solving strategy and a main driver of sustainability has been improved [19], this skill has not been trained in physics learning in the form of ESD-based curriculum analysis. In this study, ESD is a new topic inserted for students as prospective physics teachers (PPTs) in our study program. So, the first thing we do is foster PPTs’ creativity in presenting ideas based on global issues in the physics learning curriculum design. The aims of this study are described: (1) how to foster the creativity of PPTs in ESD-based curriculum analysis and (2) describing the profile of PPTs’ work as a form of ESD-based curriculum analysis.

2. Research Methods
This study was a qualitative descriptive study by observing lectures behaviour consisting of independence, integration, motivations, judgment, flexibility, evaluation, questions, opportunity, and frustration [20]. The subjects of this study were 20 prospective physics teachers (PPTs) from the superior class of the 2016 Physics Education study program who conducted a school curriculum study course in semester 5 (odd semester of 2018/2019 academic year). Also, the work of prospective physics teachers in the form of the results of curriculum analysis was assessed based on the four basic components of the curriculum, namely objectives, content, the learning process designed, and the assessment design [21]. The content prepared is expected not only to textbook material but also to global issues. The product of the curriculum study was analysed the content for physics, the global issues, and the solution to the global problem discussed.

3. Results and Discussion

3.1. How to foster the creativity of prospective physics in analysing ESD-based curricula
The creativity of PPTs is grown in several ways, namely: (1) encourage PPTs to learn autonomously; (2) have a collaborative, socially inclusive learning style; (3) motivate the PPTs to master factual
understanding so that they have a strong foundation for divergent thinking, (4) delay judging the thoughts of PPTs until they have been obviously formulated and developed, (5) foster flexible thinking, (6) promote self-assessment in PPTs, (7) seriously give the recommendations and issues of PPTs, (8) offer possibilities for PPTs to work with a broad range of materials and under various circumstances, and (9) help PPTs to learn how to deal with failure and frustration [20]. The entire process was carried out well by lecturers in the lectures on the school curriculum study for superior class students of 2016 by making a more operational checklist through 5 sub-items based on 9 items of behaviour carried out by lecturers in the classroom to foster student creativity.

The independence aspect can be carried out by encouraging PPTs to learn independently in the way: (a) encouraged the PPTs to show what they learned on their own, that is school curriculum study especially physics curriculum of national curriculum in Indonesia with inserted of ESD; (b) teach the PPTs about the basic knowledge of curriculum development and information about ESD framework, leave then to find out more about curriculum development; (c) renounce questions for PPTs to find out for themselves; (d) after teaching basics, leave space for individual learning; (e) leave open-ended question about the development of curriculum based on ESD to find the answers. This is difficult at the beginning because it requires students to be familiar with a learning strategy that expects PPTs to be fully involved and able to learn independently before fostering creativity.

The integration aspect can be carried out by (a) given opportunities to PPTs to share ideas and views about the development of curriculum, physics learning, ESD, and the others; (b) given opportunities to PPTs to do group work, in this case, they are grouped into 10 groups; (c) encouraged the PPTs to contribute the lesson in an active way in every learning activities; (d) encouraged the PPTs to ask questions and make suggestions; (e) expected the PPTs to wok in groups co-operatively. In this effort to foster creativity, lectures gave the same name give the same opportunities to all PPTs but not all of them provide active responses that are in line with expectations. They tend to be shy to ask questions so there are only a few of them who take advantage of the opportunities.

To provide motivation, the things that have been done in order to foster creativity are: (a) learning the basic knowledge about curriculum and development and information about ESD as well as the skills of ESD with good emphasize; (b) highlight the significant of mastering the basics emphasize the importance of mastering the essentials, the basics of curriculum development and ESD curriculum framework exist; (c) expect the fundamental knowledge/skills of PPTs to learn well; (d) not a major concern to move rapidly to the next subject because it takes a good emphasize on basics knowledge/skills; (e) the PPTs learning is more important than only covering the syllabus of school curriculum study courses. In this aspect, the PPTs are expected to have a meaningful experience with basic knowledge/skills before carrying out an analysis of the school curriculum based on ESD.

In the framework of the decision making, it takes a process in aspects of judgment such as (a) before taking a stand, get the PPTs to explore their thoughts; (b) follow up on PPTs’ questions to make them think; (c) did not give own views immediately on PPTs’ ideas; (d) comment on PPTs’ ideas only after more thorough exploration; (e) encouraged PPTs to do things differently, even if it takes time. Beside that, encourage flexible thinking is needed to foster creativity so the lectures must use the flexibility aspect that is: (a) probe PPTs ideas to encourage thinking; (b) encourage PPTs to ask question freely; (c) encourage PPTs to think in different direction; (d) like PPTs, it takes time to think differently; (e) allow PPTs to deviate from their instructions. But not all students take these opportunities so only a part of PPTs that can produce ESD-based curriculum analysis.

For the evaluation aspect, we should be: (a) expect PPTs to check their work; (b) offer PPTs the opportunities to share strengths and weaknesses; (c) provide PPTs inspect their work in advance of the lectures; (d) PPTs have the opportunities to assess themselves; (e) allow PPTs to demonstrate their work to each other prior to submission. But in the reality of learning, not all these evaluation items are carried out due to several obstacles including because students are not accustomed to doing self-assessments.

To foster creativity, we need the question strategies such as: (a) follow up on PPTs’ questions; (b) listen to PPTs’ questions carefully; (c) do not slightly reject the suggestion of PPTs; (d) listen to the recommendations of PPTs even if they are not practical; (e) listen patiently when PPTs ask stupid questions. Other than that the opportunity need to foster creativity through (a) encourage PPTs to experiment with what they learned; (b) appreciate placing PPTs into distinct uses what they have
learned; (c) encourage PPTs to do various stuff with which they have learned; (d) don’t worry that PPTs try their thoughts and deviate; (e) enable PPTs to go beyond what they are taught. Another thing that can foster creativity in frustrating. The lectures can foster the PPTs’ creativity through (a) giving PPTs the opportunity to come when they are frustrated for emotional support, (b) helping PPTs who experience failure to regain confidence; (c) helping PPTs to draw lesson from their failures; (d) increase frustration among PPTs as part of the learning process; (e) encourage PPTs who have not found other alternatives.

After learning about the school curriculum study by inserting an ESD curriculum framework using a strategy to foster creativity in CFTIndex developed by Kaycheng Soh [20], students are given a questionnaire of responses in the form of an attitude scale. The response questionnaire (Table 1) contained statements about students' attitudes toward the ESD-based curriculum and their experience in analysing the ESD-based curriculum.

Table 1. PPTs responses toward ESD-based curriculum analysis

| Statement                                                                 | Attitude Scale (%) |
|--------------------------------------------------------------------------|---------------------|
| ESD is a new material in the School Curriculum Study                     | SDA 5 0 5 65 25     |
| ESD is a very interesting material                                       | DA 0 0 0 35 65      |
| ESD competencies can be integrated into the physics curriculum           | N 0 0 65 35         |
| ESD is very important for students                                       | A 0 0 15 35 50      |
| I find it difficult to relate global issues to curriculum analysis       | SA 5 35 35 25 0     |
| I feel challenged and gain new experiences in analysing ESD based curricula | 0 0 5 55 40         |
| I was motivated to produce a good ESD based curriculum analysis          | 0 0 5 80 15         |
| I was frustrated when looking for solutions to global problems as a characteristic of an ESD based curriculum | 15 10 65 5 5        |

SDA=Strongly Disagree; DA=Disagree, N=Neutral; A=Agree; SA=Strongly Agree

Table 1 shows most of the PPTs agree that ESD is an interesting material and can be integrated into the physics curriculum according to the PPTs' view. But none of them strongly agree if it is difficult to relate the global issue to physics curriculum analysis. Even though the results of the curriculum analysis made by these PPTs have not fully demonstrated the integration of global issues in the physics curriculum. The neutral attitude of 35% PPTs to the difficulty to relate global issues into curriculum analysis, Mirza gives the argument, "In my opinion, the measure of the relevance of the concept of physics to global issues also depends on the context and the solution that can be resolved through physics or not."

The 25% PPTs agree with the statement, Agista is one of the PPTs that agrees, "I agree with the global issues applied to the physics curriculum. It’s just that it is quite difficult to apply the physics curriculum. Because it requires analytical skills and critical thinking skills to understand it, and this tends to be subjective. If it is indeed going to be applied, it requires instruments that are consistent enough so that differences of thought between each student can be overcome and learning objectives can be achieved properly."

Nikmatus is one of the 35% PPTs that disagree with the 5th statement because she thinks that ESD can be applied in physics learning so that physics learning can be varied and deeper for the ESD discussion. Elok gives her reason, "I feel quite understand about ESD because it has been taught by lecturers during learning before".

Ilham in one of the 5% PPTs that strongly disagree with the statement that difficult to relate global issues to curriculum analysis.

"In my opinion, the issue of ESD is increasingly vigorous because in the 21st century we are increasingly aware of the limited available resources and so it must be wise to manage them. In the era of big data as it is now very easy to obtain information depending on how we filter it, starting from Amazon forest fires which are covered by international media for almost 2
weeks, the problem of plastic waste in the sea, many people think that the issue of global warming is a hoax, to the socio-political problems between nations where the solution is the goal of education and the survival of humanity itself.”

Most of the PPTs feel challenged and gain new experiences in analysing ESD based curricula and was motivated to produce a good ESD based curriculum analysis. But 5% of PPTs agree that they were frustrated when looking for solutions to global problems as a characteristic of an ESD based curriculum. Rohma said,

“That it is difficult to find solutions to global problems as characteristic of the ESD-based curriculum. That is because they are not literate enough on emerging issues at global, national, or local levels. As with the issue of climate change issues, what appears in the media is the language of a scientist so they do not know the relevance and the influence of these issues, and what the solution is.”

Most of the PPTs have a neutral attitude about the frustration when looking for the solution to global problems as a characteristic of an ESD based curriculum. Elok thinks that whether or not it is easy to connect global issues into curriculum analysis depends on the material and its inspiration. On the other hand, 10% PPTs disagree with that statement. Nikmatus disagreed because ESD-based learning could be included in physics learning. ESD does not cause frustration, it can be easier because it is more emphasized in daily life that the use of ESD can be done in the current era. Mirza disagreed with the statement because according to her,

“Finding solutions to global issues related to ESD curriculum analysis could be communicated and involved students in related discussions. So, in my opinion, the teacher was not the only source of information and problem-solvers for solving the most problematic issues related to ESD issues.”

Different from the others, Ilham and Agista gave an argument on why they chose strongly disagree with the last statement in the questionnaire. Ilham found it very easy to find ideas and solutions to these issues. Many international organisations and individuals who submit their ideas, for example, WWF, NatGeo, WHO, etc. who not only submit their ideas but also realise them in the form of social movements, journals, magazines, etc. Agista gives the reasons below:

“I chose strongly disagree because I feel happy when learning physics is directly connected with global issues, so the concept is no longer abstract. Maybe indeed for some people it is quite difficult, but for me, I am very interested and more into, ‘Ow...so the application of the concept of physics is to solve this problem...’ And it was very helpful and made it easier for me to understand the concepts of physics, it will not be frustrating.”

Although there are quite a lot of PPTs who find it easy to connect global issues in analysing curriculum and do not feel frustrated by the search for solutions to the problems discussed, not many students can produce an integrated physics curriculum analysis with global issues and offer solutions to these problems. This can be seen in the have provided a new experience for students further explanation of the profile of the work of PPTs in the form of ESD-based curriculum analysis. Nevertheless, activities to integrate global issues in physics curriculum analysis so that they can be motivated to develop ESD-based physics learning.

3.2. The profile of PPTs’ work as a form of ESD-based curriculum analysis

The result of PPTs’ curriculum analysis based on ESD was analysed based on the components of the basic curriculum and ESD content with global issues and the offered solution of global problems.

| Group | The objectives based on basic competence of national curriculum | The physics content | The learning model used | Design laboratory activities | Assessment of learning used | Global Issue | Offered Solution |
|-------|---------------------------------------------------------------|---------------------|------------------------|---------------------------|-----------------------------|-------------|-----------------|
| 1     | Yes                                                           | Dynamic Fluid       | Classroom Discussion   | -                         | Affective, cognitive         | -           | -               |
| # | Yes/No | Topic                                      | Type                    | Methodology                      | Affective, cognitive, psychomotor | Climate Change | Cozy Tropical House |
|---|--------|-------------------------------------------|-------------------------|----------------------------------|----------------------------------|----------------|---------------------|
| 2 | Yes    | Heat Transfer                             | Cooperative Learning, Problem-Based Learning, Discovery | Real laboratory                  | Affective, cognitive, iteration skills, performance assessment, authentic assessment | Climate Change | Cozy Tropical House |
| 3 | Yes    | Mechanical Waves Characteristic           | Guided Inquiry          | Real laboratory                  | Affective, cognitive, psychomotor | Tsunami        | Power Plants Use Ocean Wave Energy |
| 4 | Yes    | Work and Energy                           | Cooperative Learning    | Real laboratory                  | Affective, cognitive, psychomotor | Renewable Energy | The bridge parabolic form for the buffer to make equilibrium and safety bridge |
| 5 | Yes    | Equilibrium                               | Problem-Based Learning  | Real laboratory                  | Affective, cognitive, psychomotor | Unsafety Bridge | -                   |
| 6 | Yes    | Refraction of Light                       | Project-Based Learning  | Projects to make the simple telescope | Affective, cognitive, psychomotor | -              | -                   |
| 7 | Yes    | Static Electricity                        | Problem Solving         | Virtual laboratory               | Affective, cognitive, psychomotor | -              | -                   |
| 8 | Yes    | The Kinetic Theory of Gases               | Cooperative Learning    | Real laboratory                  | Affective, cognitive, psychomotor | -              | -                   |
| 9 | Yes    | The Motion of the Planets and Satellites  | Project-Based Learning  | Real laboratory                  | Affective, cognitive, psychomotor | -              | -                   |
| 10| Yes    | Collision                                 | Inquiry                 | Real laboratory and virtual laboratory | Affective, cognitive, psychomotor | Frequent car accidents | Collision application for car safety calculation |

In an effort to foster the creativity of PPTs to produce an ESD-based curriculum analysis, all of them can make analysis based on the basic component of curriculum, 50% of them that can associate with global issues, and only 20% of them that provide content that pay attention to the global issues in the SDGs and provide solutions to the problems studied physically. These findings are similar to the previous study that the ability of students to integrate the ESD competences is relatively low [7]. From five global issues associated with physics material, the most interesting issue and the offered solution are given by group 2. Figure 1 shows one of the results of an ESD-based curriculum study for heat transfer which is associated with the global issue on climate change created by PPTs.
Figure 1. Content study of heat transfer associated with climate change: (a) equinox phenomenon, (b) problem solving in building home with comfortable condition in tropical climate, (c) bricklayers of cozy tropical house utilizing the principle of conduction, (d) glasses layers for windows utilizing the principle of convection, (e) green plants to reduce radiation.

Based on the equinox phenomenon presented by group 2, there is a moral message for humans to better protect the earth and better respect the surrounding natural environment. Group 2 advised that the community be wiser in responding to natural situations and conditions and be able to adapt well, be able to take advantage of the increase in the earth's temperature with positive things such as solar power, utilization in agriculture and marine affairs, and so on. In offering a solution in the form of a cozy tropical house, group 2 provides an environmental analysis so that the use of environmentally friendly materials is given more attention and reduces the use of air conditioners, socially required community organizations in building environmentally friendly homes, economically need to pay attention to spending on building materials that are more economical and utilizing natural materials that are easily found. The PPTs in group 2 can combine several aspects of ESD, namely environmental issues with social changes and economic growth [22,7]

3.3. Discussion

Based on the results of the implementation of learning using strategies to foster PPTs creativity [20] in compiling ESD-based curriculum analysis, it can be seen that there are only a few PPTs who have creativity in analysing and providing solutions to global problems in the main ESD issues. It because this is the first experience in pouring creativity into an ESD-based curriculum framework. PPTs are still fixated on the task of curriculum analysis without including ESD as other assignments in lectures programmed in the semester. Although all participating school leaders and educators are encouraged to create space (both physical and virtual spaces) and provide essential resources for teachers and students to demonstrate their creativity and imagination [23]. It is strongly suggested that interdisciplinary collaboration be used and that schools be encouraged to create partnerships with external industries and creative professionals and establish a meaningful relationship with other schools [23].

Problem-solving skills are needed to implement ESD-based learning [13]. It more attention needs to be given to the development of students’ creativity [24]. In the previous study, some students did not understand the characteristics of an appropriate learning strategy in accommodating problem-solving
skills [7]. Table 2 shows that three groups choose the learning models which practice social skills such as classroom discussion and cooperative learning, it is not suitable for the content of ESD and ESD competencies. Lectures can introduce the real-world experience and service-learning activities to support and create sustainability skills among PPTs [11]. Because sustainable development is not educational to teach PPTs that sustainability is a set event to be repeated, pre- and expertly determined [11].

Another finding is that learners who engage in service-learning acquire more advanced metacognitive skills, better skills in strategic planning and task assessment, better ability to discriminate against irrelevant data and better understand customer requirements and limitations [25]. Service-learning is a pedagogy that encourages instructional experiences involving learners, provides meaningful work, and reflects on structured operations that fulfill recognized community requirements [25-26]. Buhl et. al propose Design Thinking as an appropriate strategy to guarantee that sustainability elements are already taken into consideration in the original stage of the procedures of organizational innovation [27].

Kuo noted that creativity-relevant knowledge, expertise, and skills may not necessarily be acquired through internet-connected devices. In many circumstances, this kind of creativity-relevant resources can be obtained through reading, learning from the instructions of the educator, or even immersing the participant in an ethos full of freedom, respect, ambiguity tolerance, and open-mindedness [28]. While students in this study were not yet about the environment as requested by Kuo. Another interesting characteristic of Taiwan’s creativity education that may not be implemented perfectly in creative learning programs in other nations is building a green building, using renewable energy and adopting innovative leadership [28].

The subject learners need to work on could also trigger frustrations [11], it can foster creativity if PPTs use this situation as apart of learning processes [20]. All the adverse images of the present and the future, such as like global warming, violations of human rights, terrorism often leads to adverse emotions such as powerlessness and apathy [11] make PPTs think how to reduce the negative images into positive images so they can create some solution for the global issues discussed.

4. Conclusion
There are several findings in effort to foster student creativity in analysis the ESD-based curriculum, namely: (a) ESD is interesting materials in school curriculum study and need the effort to foster PPTs creativity in analysis the ESD-based curriculum; (b) In general, PPTs feel challenged and motivated to integrate ESD in the physics curriculum even though they have some difficulties and frustration; (c) The ability of PPTs to analysis the ESD-based curriculum is good according to the component of basics curriculum development, but still weak in integrate the global issues and offered solution as well as in selecting appropriate learning strategies for problem solving skills; (d) Student that not able to integrate ESD in analysing physics curriculum are expected to give more attention and give them well service-learning.

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