ESD for physics: how to infuse education for sustainable development (ESD) to the physics curricula?

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Abstract. The application of ESD in learning believed to be able to plan a better life by changing the mindset of students in learning to live better. This study describes how to infuse ESD to the physics curricula, so hopefully, students can think to live better through learning physics. Descriptive qualitative method used in this study to describe how to do the study of school curriculum course in prospective undergraduate in physics education so that they can insert ESD in the curriculum studies that have been conducted by researchers. Through creative problem solving and the application of creativity fostering behaviour assessment, students can produce ESD-based physics curriculum studies. There are ten topics in the physics curriculum that have included ESD.

1. Introduction
Sustainability is a definitive new scientific field that focuses on world challenges and how these challenges should be addressed [1]. Sustainable Development (SD) is one of the biggest challenges of the 21st century that based on three pillars; economic, social, and environment [2]. Education for Sustainable Development (ESD) is one of the latest issues in the study of SD. ESD overcomes the aspects frame of human dependency to the quality of the environment and access to the natural resources of our days [3]. ESD has a critical role in education for a better life in the future. This responsibility and importance of ESD are shared by UNESCO and the United Nations Economic Commission for Europe (UNECE), such education must play an essential role in supporting education's ability to address the challenges of SD [4]. In order to realize this critical role, the ESD framework promoted to every education practitioner or prospective education practitioner on important elementary issues [5] in the curriculum of educational programs. The hope is that if the critical issues of ESD integrated into the learning curriculum, everyone could gain knowledge, values, skills for sustainability [6-7] also reorienting the academic curricula [8] to help students reduce the gap between local problems and global problems [9-10]. Such as Kopnina's research findings which indicate that the children can think critically about inherent moral dilemmas in sustainable development and distinguish between different values concerning the environment [11].

Not many educational programs have integrated ESD in their learning curricula. ESD still less concerned seriously related to the development of physics (part of science) education program in higher
education [12]. Thus, skills and creativity needed in analyzing the curriculum inserting ESD into the learning curriculum, including the physics learning curriculum. As a prospective physics education graduate who has the opportunity to become a physics teacher, they should start training themself to hone their creativity in compiling a physics education curriculum that is integrated ESD in it. Why is that? Because the national curriculum in Indonesia currently emphasizes the scientific method that trains 21st-century skills. However, it has not explicitly stated about ESD in the current Indonesia national curriculum. Thus, learning in secondary schools is, of course, not all integrated with important ESD issues. Physics learning is still not oriented towards global issues and solving global problems as well as local problems [13]. Mróz et al. also find that many teachers still do not implement the ESD issue in their curriculum [14]. Given the importance of the ESD mindset for a better life in the future, this research offers to infuse ESD in the existing curriculum, especially in the physics curriculum. Because as a part of higher education, we must contribute to transforming the global society into a more suitable and equitable one [15].

Curricular development should also complement research on pedagogical approaches and their efficacy for delivering sustainability education [16]. Thus, comprehensive research is needed to apply to ESD en masse. This study initiated research on how ESD can integrate into the physics learning curriculum. In previous research, an effort has been made by researchers to foster the creativity of prospective physics teacher students to study ESD-based curricula. However, not all curriculum review works contain ESD elements because of the lack of ability to integrate the global issues and offered solutions as well as in selecting appropriate strategies of ESD-based physics learning [17]. The same thing happened to the Polish language teachers. Whereas in their daily work, they try to include the problem of sustainable natural resource management in educational programs, but they do not know actively involve students [14]. Based on the weaknesses of the previous research, a study s carried out related to the competencies needed in compiling an ESD integrated physics curriculum.

Stock states the perspective of sustainable learning by paying attention to the critical competencies in the form of learning to learn, social and civil responsibility, initiative and entrepreneurship, cultural awareness, and creativity [18]. To offer ESD, John suggests using student-centred learning and project-based learning [19]. Filho et al. suggest the role of transformation in learning and education for SD [12]. Buhl et al. were convincing that design thinking could foster sustainability-oriented innovation development [20]. In comparison, Mitchell suggests creative problem solving (CPS) for sustainability because it involves creativity, creative processes, and problem-solving skills that necessary to solve complex problems like sustainability [21]. On the other hand, the condition of students who not accustomed to doing creative learning also needs to be observed in the processes of developing their creativity. In this case, efforts are needed by researchers to foster student creativity through aspects that have been previously researched by Kaycheng Soh [22].

Based on the studies on ESD competence and how ESD was learning is carried out. CPS was chosen by authors to carry out learning by observing the creativity fostering behaviour (CFTB) by teachers in the process of practising ESD integration in school curriculum review for physics education students at one of state educational university in Surabaya. This research conducted in the odd semester of 2019/2020 in the superior class of the physics education study program. Learning is carried out face-to-face (offline) through the CPS stage in which there is an aspect of CFTB. Students are invited by teachers to be creative with review content of the physics learning curriculum by inserting ESD issues in it and the solution offered through the physics learning process. During the Covid-19 pandemic like today, it is possible to introduce, and ground ESD can be made virtual face-to-face through e-learning. Azeiteiro et al. have implemented ESD-based learning using e-learning before his pandemic. Formal e-learning programmes can provide an effective alternative to face-to-face training, allowing students to pursue their studies, in a flexible, collaborative and interactive way, whilst holding down full-time jobs. ESD in e-learning can contribute to, and have a role in, the transition to sustainable societal patterns [23].

This study describes an effort to infuse ESD to the physics curricula through the prospective undergraduate in physics education (PUPE) activities on the school curriculum course. The issues that are brought up by PUPE in the design of the physics learning curriculum are ESD issues. Besides, students also create the idea for an offered solution to solve problems for the issues they choose. So, the purposes of this study are to describe: (1) how to conduct the school curriculum course in physics
education in order to build the ESD framework; (2) how to analyze and infuse the ESD framework to the physics curricula; and (3) the profile of ESD-based physics curricula work result.

2. Method

Descriptive qualitative method is in this study. It describes how to do the study of school curriculum course in PUPE, so they can insert ESD in the curriculum studies that have been conducted by the PUPEs. There are 25 PUPEs in this course and divided into ten groups. The PUPEs learn about ESD-based physics curriculum analysis accompanied by 3 (three) lecturers. The goals of this learning are the PUPE can integrate the ESD leading issue choice to the physics curricula. To achieve this goal, we combine the CPS and the observation of CFTB. The school curriculum course conduct in one class of physics education study program in one of the state university in Surabaya. We choose CPS in this learning because CPS initially appears to be a productive approach to facilitating sustainable practice in organizations. After all, it involves creativity, creative process, and problem-solving skills [21]. To find out whether students are doing a creative process, we need a way to find out, namely through observing the behaviour of fostering creativity [22]. The aspects of creativity fostering behaviour observe by students by observation sheet. Observation by students can organize themselves in learning, or they can use self-regulated learning in this course [24]. This study also describes how the PUPE infuse ESD to the physics curricula.

The following steps obtained qualitative data:
1. Provide preliminary knowledge about the curriculum and how to design curriculum.
2. Provide a new perspective on education in the World through ESD.
3. Provide stimulation of creative thinking to train thinking skills in finding global issues that can integrate into specific physics topic.
4. Build the PUPE's internal motivation and build confidence in the creative thinking process.
5. Encourage the PUPEs to think differently: fluency and flexibility in thinking.
6. Encourage the PUPEs in finding specific topics in physical science as a basis of knowledge in finding creative solutions to selected global issues.
7. Encourage the PUPEs openness to the idea.
8. Encourage the PUPEs to built ideas or combine one idea to another.
9. Pour the ideas that PUPEs have in preparing a physics learning curriculum plan.
10. Insert selected ESD issues in the physics learning curriculum plan and provide a solution study to the issues raised using physics concepts.
11. Revise and improving work results in designing ESD-based physics curricula for specific topics.
12. Communicate the idea of integrating ESD in the physics learning curriculum on a specific topic.

These steps are an integration of the application of CPS and CFTB in the school curriculum course to infuse ESD issues into the physics curriculum.

The students observed the aspects of CFTB observe using observation questionnaire with Tursthone scale with six categories (1 until 6). The CFTB was done by the lectures very well if the score is 6 (six), five means the CFTB well done, four means the CFTB done pretty well, three means the CFTB did poorly, two means the CFTB not doing well, and one means the CFTB did not happen. The average of each CFTB aspect used to describe the compliance criteria. Table 1 shows the description of compliance criteria based on the score of the CFTB aspect.

| Score Range | Compliance Criteria |
|-------------|---------------------|
| 1.00 – 1.50 | Didn’t happen       |
| 1.51 – 2.50 | Not well            |
| 2.51 – 3.50 | Poor                |
| 3.51 – 4.50 | Adequate            |
| 4.51 – 5.50 | Good                |
| 5.50 – 6.00 | Very Good           |
3. Results and Discussion

3.1. Physics Curriculum Course with CPS and creativity fostering behaviour

Table 2 show mapping the linkages between CPS, CFTB, and the steps compiled in implementing the school curriculum course. The CPS stages can provide an opportunity for PUPEs to produce an innovative product from a physics curriculum review and present it in an ESD-based physics learning tool. CPS first described as including three distinct components: (1) understanding the problems, (2) generating ideas, and (3) planning for actions. Then in 2014, Basadur et al. depicted four-stage CPS process: generating, conceptualizing, optimizing, and implementing [25]. Researchers increasingly recognize CPS as a necessary process of stimulating creative, sustainable solution and expand into six-stages CPS. Mess finding, fact-finding, problem finding, idea finding, solution finding, acceptance finding [21].

| CPS stages [25] | CPS stages [21] | CFTB aspects [22] | The learning steps in this study |
|-----------------|-----------------|-------------------|----------------------------------|
| GENERATING      | Mess finding    | INDEPENDENCES (Encourage students to learn independently) | 1,2,3,4                          |
| It is creating options in the form of new possibilities- new problems that might be solved and new opportunities that might capitalize | Problem finding | MOTIVATION (Motivate their students to master factual knowledge so that they have a solid base for divergent thinking) |                                  |
| CONCEPTUALIZING | Problem finding | INTEGRATION (Have a co-operative, socially integrative style of teaching) | 5,6,7,8                          |
| Creating options in the form of alternative ways to understand and define a problem or opportunity and good ideas that help solve it. | Idea finding | JUDGMENT (Delay judging students' ideas until they have been thoroughly worked out and formulated) |                                  |
| OPTIMIZING      | Solution finding| FLEXIBILITY (Encourage flexible thinking) | 9,10                             |
| It is creating options in the form of ways to get an idea to work in practice and uncovering all the factors that go into a successful plan for implementation. | | EVALUATION (Promote self-evaluation in students) |                                  |
|                 |                 | QUESTIONS (Take students suggestions and questions seriously) |                                  |
Many sustainability problems are highly complex, intertwined, and messy. It cannot resolve with traditional modes of mechanistic and reductionist inquiry and decision-making. Therefore, CPS is more appropriate to use in ESD-based learning. Table 3 shows the arguments about the relevance between CPS and sustainability coverage by Mitchell [21].

Table 3. CPS and the Relevance to Sustainability [21]

| CPS stages [21] | Applied to sustainability |
|----------------|--------------------------|
| Mess finding   | “Complex and messy problem require deconstruction and active discussion of all aspects of the problem, including challenges, possibilities, concern, and opportunities. In this respect, creative brainstorming on the formulation of a clear objective plays a key role.” |
| Fact-finding   | “Fact-finding is particularly important for sustainability, as there are many interdisciplinary issues involved in decision-making. Gathering important information and facts may reveal different perspectives of the problem and provide implications for potential solutions.” |
| Problem finding| “An accurately identified sustainability problem is dependent on mess finding and fact-finding, result from which a statement of the real problem is to be defined. Defining and formulating problems in sustainability discourse can be challenging since many related issues are interconnected. Creative brainstorming and idea synthesis may result in some clearer problem definitions.” |
| Idea finding   | “Following CPS, brainstorming should be incorporated in the idea finding stage, in order to generate as many ideas or potential solutions as possible. Different creativity-driven techniques can bee adopted in order to support this divergent/convergent process.” |
| Solution finding| “In moving towards defined solutions, the main goals are to identify and evaluate and the potential and most promising alternatives. Creative brainstorm activities may help creatives to focus on those criteria which are necessary for evaluation of the ideas.” |
| Acceptance finding | “In the final CPS phase, acceptance finding, the focus is on overcoming barriers to implementation.” |

In order to carry out the CPS stages optimally, it is necessary to have the role of a lecturer who facilitates the PUPEs creativity in constructing ESD-based physics curricula. In order for learning activities to direct and able to foster self-regulated learning, observations of lecturer behaviour need to
foster the PUPE creativity in the CPS environment. For this reason, aspects of the CFTB are used by researchers to observe lecturers in assisting the PUPE in preparing ESD-based curricula. Table 4 presents the researchers' arguments about the relevance of CFTB aspects in embedding ESD in learning school curriculum course. Through the implementation of CFTB aspects by lecturers and CFTB observations by the PUPEs, the learning process of the school curriculum in the CPS environment carried out well and can foster the PUPE creativity. So that the PUPEs can produce ESD-based physics learning curriculum review products with various selected global topics. The result of the PUPEs observations on aspects of CFTB carried out by lecturers in the learning process are presented in Table 5. In general, aspects of CFTB have been carried out well by lecturers who are teaching the school curriculum subject in the superior physics education class 2017.

**Table 4. CFTB and the Relevance to Sustainability**

| CFTB Aspects [22] | Applied to sustainability |
|-------------------|---------------------------|
| Independence      | This aspect of CFTB encourages PUPEs to learn independently. If the PUPEs can learn independently, they will become life-long learners so that they can face various problems on sustainability. |
| Integration       | This aspect provides the opportunities for PUPEs to co-operate and collaborate; also, there is social integration in learning. This important to apply in solving sustainable problems that are complex and messy. Problem-solving efforts can be done together and even use interdisciplinary issues for the decision-making process. |
| Motivation        | Motivation is crucial in the problem-solving process. Internal motivation and external motivation become an essential part of the process of solving complex problems in real life. Through high motivation, the PUPEs can work hard and think smart in the process of solving problems on sustainable issues. |
| Judgement         | The lectures behaviour to delay judging students' ideas can provide opportunities and trust to the PUPEs until they have been thoroughly worked out and formulated the sustainability issue and the offered solution. |
| Flexibility       | To think critically and obtain creativity ideas, we need flexible thinking. So, the lecture must give a chance to students to think flexible until they can think fluently to obtain solution offered based on an issue raised. |
| Evaluation        | All parties of learning can evaluate sustainability issues. Not only lectures enhance evaluation, but also the students do the self-evaluation for their ideas, their process, and their product for sustainability learning. |
| Questions         | In providing direction, the lecturers can give tough questions to the ideas generated by the PUPEs. Efforts to give serious suggestions and questions can help the PUPEs solidify their ideas in solving problems with the problems studied. CFTB, in this aspect, is essential to build the PUPE's creativity and confidence. |
| Opportunity       | Many sustainability problems are highly complex and messy, so the PUPEs need the opportunities to work with a wide variety of materials and under many different conditions. This CFTB aspect helps the PUPEs to make the conceptual issues, physics topic that will integrate with ESD and optimizing their ideas in assessing global issues and solving the problems. |
| Frustration       | In the process of creativity, there are times when students experience frustration and experience distrust of their ideas. In this situation, lecturers behaviour has an important role. Lecturers can help the PUPEs to learn to cope with frustration and failure so that they dare to try the new and unusual. It can improve the PUPE's creativity on solving problems in sustainability issues. |
Table 5. The result of CFTB aspects observation by students

| CFTB Aspects | Lecturers Behaviour | Score | Compliance Criteria |
|--------------|---------------------|-------|---------------------|
| Independence | Lecturers encourage students to study independently.  
Lecturers teach students the basic of the curriculum and let students find out more.  
Lecturers leave questions for students so that students find out the answer for themselves.  
Lecturers teach students the basic of curriculum development and provide opportunities for students to study outdoors for individual learning.  
Lecturers leave open questions for students to find the answer. | 5.52 | Very Good |
|              |                     | 5.39 | Good |
|              |                     | 5.48 | Good |
|              |                     | 5.39 | Good |
|              |                     | 5.43 | Good |
| Integration  | Lectures provide opportunities for students to share ideas and views (point of views).  
Lectures provide opportunities for students to work in groups.  
Lectures encourage student to contribute to learning.  
Lectures encourage students to ask questions and provide questions in the learning process.  
The lecturer directs students to work in a group cooperatively. | 5.70 | Very Good |
|              |                     | 5.87 | Very Good |
|              |                     | 5.52 | Very Good |
|              |                     | 5.48 | Good |
|              |                     | 5.56 | Very Good |
| Motivation   | Lecturers emphasize students to learn basic knowledge and basic skill well.  
Lecturers emphasize the importance of mastering essential things for students.  
Lecturers expect students to learn basic knowledge or basic skill well.  
Moving on to the next topic quickly is not the teacher’s main concern.  
Covering the syllabus is no more important than the student learning process. | 5.26 | Good |
|              |                     | 5.48 | Good |
|              |                     | 5.21 | Good |
|              |                     | 5.09 | Good |
|              |                     | 4.52 | Good |
| Judgement    | The lecturers ask students to explore their ideas before taking a stand.  
The teacher follows up the student’s questions with questions to get them to think.  
Lecturers do not give their views directly to students ideas, but first, explore the views of other students on their friends' ideas.  
Lecturers comment on students’ idea only after a more thorough exploration of ideas.  
Lecturers encourage students to do things differently, even though it takes time. | 5.65 | Very Good |
|              |                     | 5.65 | Very Good |
|              |                     | 5.08 | Good |
|              |                     | 5.39 | Good |
|              |                     | 5.48 | Good |
| Flexibility  | Lecturers examine students’ ideas to encourage thinking.  
Lecturers encourage students to ask question freely.  
Lecturers encourage students to think in different directions.  
Lecturers like the student to take their time and think differently.  
Lecturers allow students to deviate from what they told to do. | 5.56 | Very Good |
|              |                     | 5.56 | Very Good |
|              |                     | 5.52 | Very Good |
|              |                     | 5.30 | Good |
|              |                     | 4.82 | Good |
| Evaluation   | Expect students to check their work. | 5.30 | Good |
|              |                     | 5.39 | Good |
Lecturers provide opportunities for the student to share their strengths and weaknesses. 5.35 Good
Lecturers allow students to check their work before they do it. 5.39 Good
Students have the opportunity to assess for themselves. 5.35 Good
Lecturers allow students to show each other their work before submitting it.

| Questions                                           | Rating |
|-----------------------------------------------------|--------|
| The lecturer follows up on student questions.        | 5.65 Very Good |
| Lecturers listen to student question carefully.      | 5.61 Very Good |
| Lectures do not take students lightly.               | 5.39 Good |
| Lecturers listen to student suggestions even if it is impractical. | 5.30 Good |
| Lecturers patiently listen when students ask questions that may sound silly. | 5.48 Good |

| Opportunity                                         | Rating |
|-----------------------------------------------------|--------|
| Lecturers encourage students to try what they have learned. | 5.52 Very Good |
| Lecturers value students using what they have learned in a variety of uses. | 5.52 Very Good |
| Lecturers encourage students to do things that are different from what they have learned. | 5.39 Good |
| Lecturers do not mind if students try their ideas and get sidetracked. | 5.43 Good |
| Lecturers allow students to go beyond what they have taught. | 5.35 Good |

| Frustration                                         | Rating |
|-----------------------------------------------------|--------|
| Lecturers allow frustrated students to meet them for emotional support. | 4.96 Good |
| Lecturers help the students who have failed to regain confidence. | 5.04 Good |
| Lecturers help the student to learn from their failures. | 5.26 Good |
| Lecturers encourage students to take the frustration as part of the learning process. | 5.04 Good |
| Lecturers encourage students who experience a failure to find other solutions. | 5.30 Good |

Compliance score average of CFTB aspects 5.38 Good

3.2. How to analyze and infuse ESD framework to physics curricula?
To conduct an analysis of the physics curriculum, we refer to the curriculum development component. There are 4 (four) basic components in curriculum development, namely aims, content, method, and evaluation. Figure 1 depict the components of developing a curriculum [26]. The objective component in the development of the upper secondary level curriculum consists of activities to assess core competencies, assess essential competencies, develop indicators of learning competencies, and formulate learning objectives. Core competencies and essential competencies refer to the Indonesian national curriculum as outlined in the Regulation of the Minister of Education and Culture Number 37 of 2018 [27]. In this school curriculum learning activity, the physics subject section is selected. Identifying and formulating physics learning material is the content component. Analyzing the learning tools/materials/resources/media to be used, allocating time, and developing physics learning activities based on topics and class levels is the method component. At the same time, the evaluation component carried out by developing an authentic assessment which can be in the form of an assessment of attitudes, skills, and knowledge [26].

Then, how about inserting an ESD framework in the physics learning curriculum? In order to integrate ESD in the physics learning curriculum, the first thing to do is to find global or local problems related to ESD issues, including issues regarding climate change, biodiversity, disaster risk reduction, poverty reduction, and sustainable consumption [5]. Following the CPS stages, ESD-based physics learning curriculum preparation activities will be very different from the traditional way of starting from
essential competencies. The stage of CPS used are mess finding, fact-finding, problem finding, idea finding, solution finding, and acceptance finding [21].

![Figure 1. The components of developing curriculum [26].](image)

Each stage of the development of the physics learning curriculum contains ESD issues that have found. The preparation of competency attainment indicators also pays attention to the learning topics used in transferring the physics content to be taught. The preparation of the contents of the physics learning material is related to the ESD issues that have selected. So, the delivery of the content material begins with a condition as a case study of selected global issues. Then in the presentation of the material, there is also an attempt to invite students to find solutions to problems using physics concepts. Student worksheets prepared with the nuances of ESD by using global issues as the initial problem, then the activities in the worksheets are linked to the ESD issues studied. The design for the development of learning activities to be student-centred. So that it appears that physics learning is not only a piece of transfer knowledge but also efforts to cultivate attitudes and practise thinking skills based on ESD competencies, such as critical-thinking, problem-solving, and creativity [5]. It hopes that the secondary-level students who will become the next generation can gain knowledge, values, skills for a better life and a better society [6-7]. The design of assessment not only to assess the knowledge possessed by students, but more like authentic assessment which can assess every learning process, including affective assessment, knowledge, and skills. The development of the assessment also refers to the ESD competency assessment so that the learning curriculum design can measure the achievement of ESD-based physics learning.

The explanation process on how to integrate ESD into the curriculum is unique and different from the traditional way of analyzing the curriculum. It is in line with Ceulemans and De Prins’ statements that there are unique characteristics of manuals and method which can mainly situate by combining the approach and the emphasis on both the SD related content and the methods in which these elements can be taught [28]. Flexible thinking also needed to introduce the ESD framework to the students, such Elnashaie et al. that suggested using two general approaches (decentralized and centralized) to introduce sustainable development into chemical and biological engineering education [29]. Integrating sustainability into diverse academic curricula has been recognizing to be essential for providing students with the skills and insights to help society become more sustainable [30]. That is why we try to infuse ESD in designing a physics learning curriculum.

3.3. *The profile of PUPEs work to infuse ESD in the physics curricula.*

Researchers conducted it through school curriculum course in the CPS environment by paying attention to CFTB in the process of assisting the PUPEs in compiling an ESD-based physics curriculum. The PUPEs produced ten (10) products of physics learning curriculum design. All of these products have
inserted global issues in ESD and provided design learning with learning nuances with ESD topics that were found-selected-solution sought by the PUPEs. The PUPEs then analyzed the ten topics for their suitability with the completeness of the essential components of the curriculum, ESD content with specific global issues, and the offer of solutions given by the PUPEs in overcoming the problems being studied [26].

Based on the result in Table 6, we know that there is ten product of the PUPEs work on ESD-based physics curricula. All of them can identify the global issues that integrated into the design of the ESD-based physics learning curriculum. All of the PUPEs groups can formulate the objectives based on basic competence of national curriculum that inserted with the issues of ESD. They can relate certain physical concepts to the global problem studied. The learning models selected in designing learning activities are student-centred learning models that can practice thinking skills that are part of ESD competencies. It is in line with the suggestion of John [19]; the PUPEs can grasp this idea in compiling an ESD-based curriculum review. There is a variation of laboratory design activities in their work result, namely real labs, virtual labs, and projects. However, some the PUPEs have not finished drafting an assessment in the physics learning curriculum design they are working. Group 8 and group 10 experienced a long process in determining global problems to be studied in physics learning. Maybe this is an obstacle that also occurred in previous studies so that only 50% of PPTs could compile an ESD-based curriculum design [17].

Nevertheless, in this lecture activities, these PUPEs can find ESD-based global issues that will be studied in physics learning, although it requires enough time and patience in the process. It is where the role of CFTB in assisting students to foster creativity in the CPS environment. However, some groups constrained by time in completing all ESD-based curriculum development project tasks in the assessment design section. All groups were able to analyze and identify problems using physics concept so that they could offer a solution based on the studies they had done.

Table 6. The profile of PUPEs work on ESD-based physics curricula

| Group | Title/Topic                                                                 | The objectives based on basic competence of national curriculum | The physics content | The learning model used | Design lab. act. | Authenti c Assessment | Global Issue | Offered Solution |
|-------|----------------------------------------------------------------------------|---------------------------------------------------------------|--------------------|------------------------|-----------------|----------------------|--------------|-------------------|
| 1     | A simple fire detection tool: developing ESD-based temperature and heat learning. | Yes | Temperature and Heat | Project-Based Learning | Real Lab | Authenti c Assessment | Fire | Used heat sensor for a simple fire detection tool |
| 2     | Management of Seawater into Ready-to-Drink Water: the ESD-based Evaporation Pyramid Method. | Yes | Energy Source | Problem-Based Learning | Real Lab | Cognitiv e, Skills | Global water crisis | Evaporation pyramid method for seawater into ready-to-drink water |
| 3     | ESD-based Spring Vibration Learning to Improve Students’ Critical-Thinking Ability in Designing Earthquake Resistant Buildings. | Yes | Vibration | Project-Based Learning | Real Lab | Authenti c assessment | Earthqua ke | Designing Earthquake Resistant Buildings |
| 4     | The use of waterfall-based-renewable-energy. | Yes | Energy | Problem-Based Learning and | Real Lab | Authenti c Assessment | Renewa ble Energy | Microhydro technology |
### 3.4. Discussion

In order to engage academics in ESD, it is necessary to develop a more explicit rationale for the adoption of ESD pedagogy in higher education and conduct further empirical research on the views, practices, and visions of those academics not involved in ESD [31]. On the other hand, a small portrait of the real conditions of learning physics in the field shows that the basic knowledge of NOS is still in the adequate [32]. To realize ESD in the physics curriculum, it requires a good understanding of physics content. It also requires sensitivity to local and global issues. It can think critically, problem-solving, and creativity to offer solutions to the problem being studied [15]. Thus, extra efforts are still needed to provide rationality to all components of society about the importance of ESD in learning so that they can develop the skills and attitudes of the community in dealing with local, regional, and global issues related to the environment through ESD [33].

As part of higher education, we have an essential role to play in contributing to understanding ESD in society. ESD is something that needs to be understood and applied in learning to open insights and become the basis of dealing with sustainable life with increasingly complex and messy problems. Through the application of ESD in learning, it hopes that every next generation will have an awareness of the importance of sustainability learning, about the importance of environmentally friendly technology, and about the importance of protecting the earth and the world community. According to Filho et al., "Universities should transform to serve as models of social justice and environmental..."
stewardship and to foster sustainability learning" [12]. For this reason, it is necessary to initiate learning to integrate global issues and efforts to solve problems.

We made our first initiation in learning the school curriculum in small scale with an effort to foster the creativity of prospective physics teacher students in compiling an ESD-based physics curriculum review and effort to compile ESD-based science learning tools for postgraduate students [10,17]. The implementation of ESD-based learning needs problem-solving skills and creativity [34-35]. However, some postgraduate science students did not understand the characteristics of learning strategies appropriate to accommodate problem-solving skills and creativity when compiled ESD-based science learning tools [10]. It also happens to prospective physics teachers students in the previous implementation of ESD learning in the school curriculum course [17]. It is because most university students are still familiar with the traditional way of analyzing the curriculum which refers altogether to the essential competencies of the curriculum without further development, and there is still need more literacy about the characteristics of the learning model/strategy. It could also be because the learning environment is not supportive in the process of drafting the ESD-based curriculum.

In order to enhance sustainability-based curricula, academics should develop collaborative approaches and discuss how to redesign their disciplines, and how to appreciate the epistemology and multicultural; vision of sustainability, both as a topic and as a field of education research [12]. In this study, lecturers and the PUPEs had a basic understanding and shared perception regarding the ESD-based curriculum at the beginning of the lecture. Besides, the lecturer also emphasized that students can think freely and openly to find ideas to integrate global issues into the design of the ESD-based physics learning curriculum. Lecturers carry out the selection of CPS and CFTB in s effort to provide a learning environment that can nurture efforts to find-analyze-solve problems and build creativity in integrating ESD in the physics curriculum. Regarding attitude and curricula, sustainability-related coursework can have positive impact sustainability awareness, since students pursuing a sustainability-related minor or major emphasized the social aspects of sustainability more than their peers only seeking disciplinary specialization [36]. So there have been efforts to incorporate sustainability into the courses, although there is potential for further improvement [37].

4. Conclusion

This study concludes that the effort to insert ESD into the physics curriculum has been implemented in the school curriculum course through the CPS learning environment by observing CFTB foster student creativity. The CPS stage is crucial to find ideas to offer solutions to the sustainability problems that are studied. The result of CFTB observations shows that behavioural aspects of fostering creativity carried out by lecturers carried out well. Curriculum analysis activities by integrating ESD are carried out through the CPS stage and paying attention to ESD issues in preparing physics learning curriculum planning at the secondary level. The PUPE can follow the learning process by producing ESD integrated physics curriculum analysis products. The PUPEs can find global issues and offer solutions that match to the problems studied. The implementation of learning by integrating CPS and CFTB requires patience and diligence so that all parties can have the same goal. Students who are not familiar with the CPS learning pattern will need a longer time to produce a curriculum analysis product. Therefore, it recommended for researchers or practitioners who will then use this method to prepare all the possibilities that will occur, both in term of material content, student readiness, even patience in maintaining the same goals until the course end.

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References

[1] Ramísio P J, Pimto L M C, Gouveia N, Costa H and Arezes D 2019 J. Clean. Prod. 222 300-309
[2] WCED 1987 Report of the world commission on environment and development: our common future. Available at: http://www.un-documents.net/our-common-future.pdf
[3] Suduc A M, Bizio M and Gorgi G 2014 Procedia Soc. Behav. Sci. 116 1187-1192
[4] Bentham H, Sinnes A and Gjatterud S 2015 Int. J. High. Educ. 4 (4) 158-177
[5] Kankovskaya A R 2016 Procedia CIRP 48 449
[6] Dannenberg S and Grapentin T 2016 J. Futures Studies 20 (3) 7
[7] Klarin T 2018 Zagreb Int. Rev. Econ. Bus. 21 (1) 67
[8] Azeiteiro AM, Bacelar-Nicolau P, Caetano F J P and Caeiro S 2014 Procedia Soc. Behav. Sci. 116 1187-1192
[9] Gosselin DC, Manduca C, Bralover T J, and Mogk D 2013 Eos, Transactions, American Geophysical Union 94 (25) 221
[10] Hariyono E, Abadi, Liliasari, Wijaya A F C, Fujii H 2018 J. Penelit. Fis. Apl. 8 (2) 61
[11] Kopnina H 2014 Studies in Educational Evaluation 41 124-132
[12] Filho W L, Raath S, Lazzarini B, Vargas V R, de Souza L, Anholon R, Quelhas OLG, Haddad R, Klavins M and Orlovic V L 2018 J. Clean. Prod. 199 286295
[13] Azeiteiro U M, Bacelar-Nicolau P, Caetano F J P and Caeiro S 2015 J. Clean. Prod. 106 308-319
[14] Brundiers K & Wiek A 2010 Innovation High. Educ. 36 (2) 107
[15] Watson M K, Lozano R, Noyes C and Rodgers M 2013 J. Clean. Prod. 61 106-116