The Development of Science Teaching Materials Based on the PjBL-STEM Model and ESD Approach on Environmental Pollution Materials

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Abstract. Critical thinking skills and sustainability consciousness are competencies that students need to have to face the challenges of the 21st century and can be developed through appropriate learning activities and teaching materials. Unfortunately, teachers do not have the right guidelines and teaching materials to implement learning activities that develop those competencies. This study aims to develop science teaching materials with the PjBL-STEM learning model and education for sustainable development (ESD) approach on environmental pollution material to enhance critical thinking skill and sustainability consciousness of junior high school student in class VII. The teaching materials developed in this study are Lesson Plans, Worksheets, and assessment for critical thinking skill and sustainability consciousness. The research method used in developing the product is research and development (R & D). While the R&D research model used is the four-D development model. The four-D development model has several stage, namely define, design, develop, and disseminate. This study solely reached the development stage. The feasibility test was carried out by the experts. The data were analyzed using percentage of the product eligibility in the validation form. Based on the results of the feasibility validation, the critical thinking skill assessment validation received a percentage value of 85% with very feasible criteria and sustainability consciousness assessment validation received a percentage value of 97% with very feasible criteria. The finding of the research indicate that the teaching material developed is valid and eligible to use.

Keywords: Teaching Materials, PjBL-STEM, ESD

Introduction

Critical thinking skills and sustainability consciousness are important skills for students to master in facing the challenges of the 21st century. Critical thinking skills help students to get used to thinking analytically, investigatively and solving problems (Komala, et al., 2017; Foo & Quek, 2019; Thampy, et al., 2019). The learning objectives ideally guide students to be able to adapt in the real world, become critical and creative thinkers, problem solvers, and decision makers (Anggraini & Sriyati, 2019; Persky, et al., 2019). This problem-solving ability needs to be coupled with sustainability consciousness so that the solutions used in solving problems are sustainable solutions. This means that the solution is not only useful for that period, but also useful for the next generation (Berglund, 2014). With these sustainability characteristics, critical thinking skills and sustainability
consciousness are appropriate competencies to realize the sustainable development goals (SDGs). The SDGs are a program launched by world leaders at the 2015 UNESCO meeting. The sustainable development goals include (1) no poverty, (2) no hunger, (3) healthy and prosperous lives, (4) quality education, (5) gender health, (6) clean water and proper sanitation, (7) clean and affordable energy, (8) decent work and economic growth, (9) industry, innovation and infrastructure, (10) reducing inequality, (11) cities and sustainable settlements, (12) responsible consumption and production, (13) climate change management, (14) ocean ecosystems, (15) terrestrial ecosystems, (16) peace, justice and resilient institutions, (17) partnerships to achieve goals (Michelsen & Wells, 2017).

In 2015 the SDG concept was put into the world of education in the form of Education for Sustainable Development (ESD) (Sarabhai, 2015). It aims to build human character and competence through education in schools to create a society with sustainable living behavior as stated in the SDGs (Sarabhai, 2014). But unfortunately in Indonesia, ESD has not been included and implemented in the school curriculum. So there is no reference to learning strategies and teaching materials from the government that are suitable for implementing learning activities with the ESD concept. The appropriate learning strategy to be applied with the ESD concept is a learning model that is inquiry, student-centered and trains students to solve problems related to everyday life (Kalsoom, 2017).

Project-based learning model (PjBL) is a strategy, approach or learning method that aims to provide meaningful experiences for students and develop students' critical thinking skills through problem solving activities. With PjBL learning, students are able to solve problems using information obtained so as to form a concept by showing a solution to the problem (Furi, et al., 2018). PjBL can also improve students' environmental attitudes towards waste management (Susilawati, et al., 2017). Meanwhile the STEM approach integrates aspects of science, technology, and technology techniques, and mathematics (Setyowati, et al., 2021), so the PjBL-STEM model helps students solve real-life problems and train higher-order thinking skills (Afriana, et al., 2016; Ralph, 2016; Sulisworo & Kaliappen, 2021; Nurhidayah, et al., 2021).

The PjBL-STEM model encourages students to understand concepts through problem identification and product creation as a solution to these problems (Laboy-Rush, 2010). Laboy-Rush (2010) also explains that there are 5 stages of PjBL-STEM, namely reflection, research, discovery, application and communication. Therefore PjBL-STEM is a learning model that is in accordance with the ESD approach. To achieve optimal learning activities, teachers need learning resources to convey information and students need teaching materials as study guides and references. Less than optimal teaching materials are a common problem which is one of the reasons for the inadequate quality of education and learning systems (Kaniaiwati, et al., 2016). It is necessary to update the currently circulating teaching materials by considering the appropriate learning model in order to achieve learning objectives (Nasution, 2018). Unfortunately, teachers in Indonesia do not have sufficient guidelines and teaching materials to implement learning activities that develop both critical thinking skills and sustainability consciousness.

The use of teaching materials can help to train students' ability in solving problems by using critical thinking skills and sustainability consciousness to conduct investigations, draw conclusions and produce sustainable solutions. Thus, researchers developed teaching materials using the PjBL-STEM learning model with the ESD approach to environmental pollution material to improve students' critical thinking skills and sustainability consciousness. PjBL-STEM teaching material with the ESD approach on environmental pollution material is expected to be a reference for teachers to apply ESD in science learning activities at school. Therefore the aim of this study is to develop teaching materials based on PjBL-STEM with ESD approach on environmental pollution material to enhance critical thinking skill and sustainability consciousness of junior high school student.
Methods

The development of teaching materials uses the Four-D model by Thiagarajan (1974). In the Four-D model, the stages include the stages of defining, designing, developing and disseminating. This research only conducted up to the development stage. The instrument used was a validation form. Validation is carried out by expert validators. After being declared valid by the validators, the teaching material was ready for practicality test by the teacher and students. The final data obtained is in the form of quantitative data using the Guttman scale and qualitative data in the form of comments and suggestions. The analysis technique uses descriptive analysis by calculating the average answer score for each aspect of the product (Arikunto, 2013). The criteria obtained will be used as a consideration in product development and improvement. In interpreting and concluding the data, the percentage of product eligibility can be used. Product eligibility is determined based on the criteria shown in Table 1.

Table 1. Teaching Material Eligibility Criteria

<table>
<thead>
<tr>
<th>Interval (%)</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>81-100</td>
<td>Very worthy</td>
</tr>
<tr>
<td>61-80</td>
<td>Worthy</td>
</tr>
<tr>
<td>41-60</td>
<td>Pretty worthy</td>
</tr>
<tr>
<td>21-40</td>
<td>Less worthy</td>
</tr>
<tr>
<td>0-20</td>
<td>Not worthy</td>
</tr>
</tbody>
</table>

(Source: Ridwan, 2010)

Results and Discussion

The teaching materials of the PjBL-STEM model with ESD approach developed consists of worksheet, syllabus, lesson plans, and assessment instruments for critical thinking skill and sustainability consciousness. There are steps taken to develop the product so as to produce teaching materials. The following are the steps in the define, design and develop stage.

Determination of Teaching Material Design. The stage of determining the design of teaching materials is done by selecting teaching materials first. Selection of teaching materials in the form of selection of print-based teaching materials. The teaching materials developed are in the form of Worksheet, syllabus, lesson plans and assessment instrument. Teaching materials in the form of worksheet are able to help students in learning by being applied to the real world. The definition stage is carried out by conducting an initial analysis for the material to be developed, namely KD 3.8 in science lessons for class VII SMP/MTs. After that, conduct an analysis of students which aims to determine the characteristics of students. Next, analyze the tasks and materials in KD 3.8 to be developed into Worksheet and learning objectives. This is in accordance with Nurdin (2016) explaining that teaching materials or learning materials need to be chosen properly so as to optimally assist students in achieving Competency Standards and Basic Competencies.

The selection of the format of teaching materials is the second stage in determining the design of teaching materials. Format selection is a guide for designing teaching materials. The teaching materials in the worksheet are divided into 2 stages, namely LKPD 1 and LKPD 2. LKPD 1 contains reflections on pollution problems, investigations of causes, impacts and solutions to pollution of the Ngringo River. While LKPD 2 contains the discovery and creation of projects to solve environmental pollution problems. Both worksheets was
designed based on PjBL-STEM model and ESD approach. Therefore the worksheet contains five steps of learning as in PjBL-STEM model by Laboy-Rush (2010). The PjBL-STEM learning model on the student worksheet has 5 stages in student learning activities, namely (1) reflection, at this stage students reflect on environmental pollution problems through question and answer discussions with the teacher to make problem formulations; (2) investigating (research), at this stage students understand the concept of environmental pollution by seeking information in order to solve problems; (3) discovery, at this stage students find the project design by determining the tools and materials as well as the project design; (4) application, at this stage students apply and test designs to answer problems by connecting concepts between disciplines and based on the 3 pillars of ESD; (5) communication, at this stage students explain and present the results of the project they have made. Each step is related to ESD dimensions, namely social, economy and environment as mentioned by Sarabhai (2015). By adding the PjBL-STEM model and the ESD approach, it is hoped that this worksheet can help enhance critical thinking skills and sustainability consciousness of junior high school students in science learning at school.

PjBL-STEM Model and ESD approach Lesson Plan is divided into 4 meetings. Each meeting in the Lesson Plan has the content of Science, Technology, Engineering and Mathematics. They also have five steps of learning as in the PjBL-STEM model. Each step contains ESD context which has 3 dimensions, namely economic, social and environmental. By adding the PjBL-STEM model and the ESD approach, it is hoped that this lesson plan can help enhance critical thinking skills and sustainability consciousness of junior high school students in science learning at school.

The assessment instruments made are instrument that measures students' critical thinking skills and sustainability consciousness. The instrument of critical thinking skills is in the form of essay questions consisting of 10 questions. The indicator used to measure critical thinking skills in this research is Ennis's (2011) critical thinking skills indicator. In his book Ennis (2011) explains that there are 5 indicators of critical thinking skills, namely (1) providing simple explanations, (2) building basic skills, (3) concluding, (4) providing further explanations, and (5) providing strategies and tactics.

Meanwhile, the instrument used to measure the sustainability consciousness of students in this study was the sustainability consciousness questionnaire. This questionnaire was adapted from the SCQ (Sustainability Consciousness Questionnaire) developed by Gericke et al (2019). The questionnaire consists of 20 statements containing the 3 pillars of ESD, namely economic, social and environmental. The competencies measured in this questionnaire consist of 3 aspects, namely sustainability knowingness, sustainability attitude, and sustainability behavior. Assessment of the sustainability consciousness questionnaire uses a Likert scale with a score of 5 for the answer choices "strongly agree to a score of 1 for the answer choice "strongly disagree".

**Preparation of Initial Draft of Teaching Materials.** The preparation of the initial draft was carried out by compiling the student worksheet of the PjBL-STEM model and ESD Approach. Furthermore, the preparation of the syllabus, lesson plans, and teaching materials assessment instruments was carried out. The results of the design stage in the form of student worksheet teaching materials, syllabus, lesson plans, and assessment instruments were then tested for validation by experts.

**Development of Teaching Materials.** Teaching materials developed following the STEM-PjBL learning model with ESD approach to enhance critical thinking skill and sustainability consciousness can be seen in Table 2.
Table 2. The link between PjBL-STEM, ESD, critical thinking skills and sustainability consciousness

<table>
<thead>
<tr>
<th>Step</th>
<th>PjBL STEM Syntax</th>
<th>ESD Dimensions</th>
<th>Critical Thinking Skills Indicator</th>
<th>Sustainability Consciousness Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reflection</td>
<td>Environment</td>
<td>Elementary Clarification Basic Support</td>
<td>Environment Knowingness</td>
</tr>
<tr>
<td>2</td>
<td>Research</td>
<td>Economy, Social, Environment</td>
<td>Inference Advanced Clarification Strategies and Tactics</td>
<td>Environment Attitude Economic Attitude Social Attitude Economic Knowingness Social Knowingness Environment Knowingness</td>
</tr>
<tr>
<td>3</td>
<td>Discovery</td>
<td>Social, Economy, Environment</td>
<td>Strategies and Tactics</td>
<td>Environment Behavior Social Behavior Economic Behavior</td>
</tr>
<tr>
<td>4</td>
<td>Application</td>
<td>Social, Economy, Environment</td>
<td>Strategies and Tactics</td>
<td>Environment Behavior Social Behavior Economic Behavior</td>
</tr>
<tr>
<td>5</td>
<td>Communication</td>
<td>Social, Environment</td>
<td>Strategies and Tactics</td>
<td>Environment Behavior Social Behavior</td>
</tr>
</tbody>
</table>

The product feasibility test consists of a feasibility test for worksheet, Lesson Plan and assessment instrumen for critical thinking skill and sustainability consciousness carried out by lecturers in the Science Education Department, Universitas Pendidikan Indonesia. In the assessment worksheet and Lesson Plan, the validator makes an assessment by providing comments and suggestions. The results of the assessment show that the worksheet and Lesson Plan are feasible to use with improvements. This means that the worksheet and lesson plan are suitable for use after improvements have been made by the researcher as suggested in the comments column.

The improvements referred to in the Worksheet include clarifying operational verbs for student activities that indicate which activities are in accordance with the indicators of critical thinking skills and sustainability consciousness. The stages of the PjBL-STEM model must also be in the worksheet. The validator also suggests the use of clear and appropriate image media in accordance with learning activities. Meanwhile in the Lesson Plan, the validator suggests clarifying the learning objectives at each meeting. In addition, it is necessary to emphasize which part of student activities are expected to be able to enhance students' critical thinking skills and sustainability consciousness. In contrast to Lesson Plans and worksheets, the calculation of the validation of critical thinking skills and sustainability consciousness assessment instruments is carried out quantitatively by taking into account certain aspects of the assessment. The result of critical thinking skill assessment validation can be seen in Table 3.
Table 3. The Average Result of the Critical Thinking Skill Assessment Validation

<table>
<thead>
<tr>
<th>No</th>
<th>Suitability of Questions with Critical Thinking Skill Indicators</th>
<th>Percentage of Eligibility</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Validator 1</td>
<td>70</td>
<td>Very Worthy</td>
</tr>
<tr>
<td>2</td>
<td>Validator 2</td>
<td>100</td>
<td>Very Worthy</td>
</tr>
<tr>
<td></td>
<td>Average score of eligibility</td>
<td>85</td>
<td>Very Worthy</td>
</tr>
</tbody>
</table>

The results of the eligibility test of teaching materials for critical thinking skill assessment instrument showed an average percentage of eligibility of 85% with very worthy criteria. On the other hand, the result of sustainability consciousness assessment validation can be seen in Table 4.

Table 4. The Average Result of Sustainability Consciousness Assessment Validation

<table>
<thead>
<tr>
<th>No</th>
<th>Assessed aspects</th>
<th>Percentage of Eligibility</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The questionnaire is equipped with instructions for filling out the questionnaire</td>
<td>100</td>
<td>Very Worthy</td>
</tr>
<tr>
<td>2</td>
<td>Instructions for filling out the questionnaire are clear and easy to understand</td>
<td>100</td>
<td>Very Worthy</td>
</tr>
<tr>
<td>3</td>
<td>The statement is in accordance with the category of knowledge, attitudes and behavior of Sustainability Consciousness</td>
<td>90</td>
<td>Very Worthy</td>
</tr>
<tr>
<td>4</td>
<td>The statement is in accordance with the three pillars of Sustainability Development (social, economic, environmental)</td>
<td>90</td>
<td>Very Worthy</td>
</tr>
<tr>
<td>5</td>
<td>Using correct, simple, and communicative Indonesian</td>
<td>100</td>
<td>Very Worthy</td>
</tr>
<tr>
<td>6</td>
<td>Using sentences that are easy to understand and do not cause double interpretation</td>
<td>100</td>
<td>Very Worthy</td>
</tr>
<tr>
<td></td>
<td>Average score of eligibility</td>
<td>97</td>
<td>Very Worthy</td>
</tr>
</tbody>
</table>

The results of the eligibility test of teaching materials for sustainability consciousness assessment instrument showed an average percentage of eligibility of 97% with very worthy criteria. This is in line with the opinion of Emzir (2011) that before testing teaching materials must be validated. Teaching materials are said to be valid if they meet certain criteria. Plom (2007) explains that a product's characteristics are said to be valid if they reflect state-of-art knowledge. Then According to Scarvia B and Anderson (in Suharsimi, 2009) explained that, "A test is valid if it measures what it purpose to measure". This means that a test is said to be valid if the test can measure what is intended to be measured. This is known as content validation.
Conclusion

This research produces STEM-PjBL-based teaching materials on the topic of environmental pollution as an opportunity to improve students' critical thinking skills and sustainability consciousness. Based on the results of the feasibility validation, the critical thinking skill assessment validation received a percentage value of 85% with very feasible criteria and sustainability consciousness assessment validation received a percentage value of 97% with very feasible criteria. The development of teaching materials based on the PjBL-STEM model and ESD approach on environmental pollution is an effort made to facilitate teachers in implementing ESD as an approach to science learning in junior high schools.

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