Development of STEM-based Physics Worksheet with PIRPOSAL Engineering Design Process Model to Improve Creative Thinking Skills

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Abstract. Creative thinking is the most important part of 21st century education in Indonesia. In learning physics, the creative thinking skills of students in Indonesia are low. The purpose of this study was to determine the improvement of creative thinking skills on fluency indicators based on the results of the development of STEM-based physics worksheet with the EDP PIRPOSAL model. The research method used is R&D using the ADDIE model up to the ADD stage only. The development stage uses a limited trial. The sample used was students of Class ten in senior high school Banda Aceh, Indonesia. Data collection instruments used validation sheets, creative thinking skills tests, student and teacher response questionnaires. The results of this worksheet validation obtained a score of 3.53 from media experts, 3.42 from material experts, 3.70 from linguists, and all three were categorized as very valid. The response of students and teachers to this worksheet obtained a percentage of 84% and 95.31% in the very good category. Based on the results of the N-Gain test, a value of 0.97 was obtained in the high category. So that STEM-based worksheet with EDP PIRPOSAL model can improve students' creative thinking skills on fluency indicators in physics learning.

Keywords: EDP, STEM, PIRPOSAL Model, Worksheet, creative thinking skills, fluency.

1 Introduction

The ability to think creatively is a thought that tries to create new ideas. Creative thinking is important for everyone, not only in learning activities at school but also when dealing with the real world [1]. People in the 21st century are increasingly aware of the importance of a creative, proactive, and well-educated young generation. Especially the formation of young people who are skilled at solving problems by thinking creatively and understanding the concept of the problem both individually and in groups [2]. Creative thinking is one of the most important parts of 21st-century education in Indonesia. Students' creative thinking abilities are currently still

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relatively low; this is in accordance with 2015 GCI (Global Creativity Index) research showing that Indonesia is ranked 115th out of 139 countries with a global creativity index of 0.202 [3]. Meanwhile, the results of the Trend International Mathematics and Science Study (TIMSS) state that the level of creative thinking skills of students in Indonesia is low because only 2% of Indonesian students can work on high and advanced category questions that require creative thinking skills to solve them [4].

Based on the results of interviews with physics subject teachers on November 22, 2022, at senior high school in Banda Aceh, Indonesia information was obtained that 1) there is still a class minimum of 75. 2) Students have difficulty analyzing and solving physics problems if the diction of the problem is different from the examples given by the teacher in that field of study. 3) The teacher has not used the observation sheet for assessing creative thinking skills during learning. 4) 70% of class learning is teacher-centered learning. 5) The worksheet used is not STEM-based with the PIRPOSAL model; the worksheet that is commonly used has a simple form. Teacher-centered learning causes students to lack a complete understanding of concepts. Weak creative thinking in students' fluency indicators can be seen in the learning process when working on the questions given. If given questions with the same concept but with different diction or higher questions, students often experience confusion in answering these questions. This is in line with previous research [5], which stated that students experienced difficulty answering physics questions that measured their creativity skills. The existence of conceptual errors is one of the factors that makes it difficult to improve creativity. The better the concepts students have, the easier it is to come up with new ideas and develop their creative abilities.

The results of the interviews and the data obtained indicate that creative thinking skills need to be improved so that students are able to have the ability to think divergently, namely generating lots of ideas, lots of answers, lots of problem solving, lots of questions smoothly, giving lots of ways or suggestions for doing various things, and thinking about more than one answer, which is an indicator of creative thinking, namely fluency [6]. Because fluency indicators can make it possible to study problems systematically, formulate innovative questions, and design and provide ideas to solve problems [2]. Teaching material is needed to improve creative thinking skills. Learning tools that support students' creative thinking skills are student worksheets [7]. One of the worksheet that is interesting, innovative, and improves students' creative thinking skills is the STEM-based worksheet. Based on the research, it states that "STEM-based worksheet is effective for training creative thinking skills because there is an increase in scores on students' test results". This can happen because the characteristics of STEM-based worksheets are equipped with problems as well as simple experiments and projects related to STEM aspects. [8] [9]. STEM is an approach that integrates the four elements of science, technology, engineering, and mathematics [10]. Based on research conducted by [11], it was stated that "STEM calls for a shift in learning process methods from conventional methods centered on the teacher (reliant on knowledge transfer) towards learning methods centered on the student (relying on activity, hands-on activity, and student collaboration). STEM in the classroom is designed to give students the opportunity to apply academic knowledge in the real world".

One of the successes in STEM is defined by engineering as a force that supports problem-solving [12] and [13]. Engineering is a phase that is one of the characteristics of STEM-based learning activities. Engineering Design Process (EDP) is one of the initiatives available for implementing STEM education. EDP not only helps students find one solution to a problem but also helps them realize that there is more than one

right solution to solve the problem [14]. It is consistent with the opinion [2] stated that creative thinking can enable one to solve problems systematically, formulate innovative questions, and design a variety of solutions that are original. The difference between the research to be conducted and the previous research lies in the material used and the worksheet to be structured using one type of EDP, namely the PIRPOSAL model, which has eight stages consisting of problem identification, ideation, research, potential solution, optimization, solution evaluation, modifications, and learned outcomes [15]. This model puts problems at the core of the teaching process, applies gradual teaching to the entire teaching framework, and is able to guide students in the learning process of their knowledge [16]. According to [5], learning by using the PIRPOSAL model can train students to develop the skills of the 21st century, namely critical thinking and creative thinking skills. Therefore, this study aims to identify improvements in creative thinking skills on fluency indicators based on the results of the development of STEM-based physics worksheet with the PIRPOSAL model EDP step.

2 Method

The approach used in this research is a quantitative one. The research was conducted using the research and development (R&D) method. The product developed from this research is a STEM-based physics worksheet with the PIRPOSAL engineering design process model to enhance creative thinking skills. The development design that will be used in this research is ADDIE, which consists of five stages that cover analysis, design, development, application, and evaluation. But in this study, the researchers only restricted development to the stage of development. The researchers modified the design of the development as needed. As to the steps to be taken on this study, they can be seen in Fig. 1

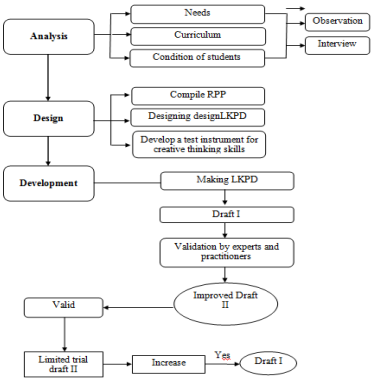

Fig. 1. Modified ADDIE research stages

Field testing using pre-experimental design research design with the model used being the One Group Pretest-PosttestThe Model One Group pretest-posttest design is carried out against one group without the presence of a control group or comparator. Pre-experimental design research design patterns with the One Group Pretest-Posttest model are as follow in Table 1.

Table 1. Research design patterns

School	Pre-test	Treatment	Pos-test
Senior High School Banda Aceh	O_1	X	O_2

In the context of a scientific experiment, the variables O1 and O2 represent the pre-test and post-test values, respectively. These values are essential in assessing the impact of a treatment. The treatment, denoted as X, involves the application of a STEM-based physics Learning and Teaching Material (worksheet) using the PIRPOSAL engineering design process model.

The implementation of this research is located in Senior High School Banda Aceh in the academic year 2022-2023. The study will take place from May 24 to 31, 2023. The population of this study is the total number of students in X class of high school, Banda Aceh, for the academic year 2022-2023. The sampling technique used in this research is purposive sampling. The sample in this study consists of one class, namely class X science in Senior High School Banda Aceh. In this study, there was only one group that served as a control group (before the trial was announced) or an experimental group (after introducing the test treatment).

The instruments used in this study are the test instrument and the non-test instrument. The test instrument in this research consists of a written pre-test and post-test. The pre-test is used to see the student's creative thinking skills on the enterprise material and energy that the student possesses before being treated, while the post-test is used to see the improvement of the students' creative thinking abilities on the concept of enterprise and energy after having been treated by applying the steps of the EDP model PIRPOSAL in worksheet with the STEM approach. Whereas the instrument in the study is composed of the learning devices (lesson plan and worksheet), the student response train, and the teacher response train, The learning device was used to support the learning process during the two enterprise materials and energy meetings. While elevating student and teacher responses to this study is used to obtain responses after applying the EDP phase of the PIRPOSAL model in STEM-based worksheet.

2.1 Analysis of Validation Sheets for Learning Devices and Test Questions

This evaluation sheet will be given to lecturers who have specified expertise in the field of STEM and the material developed. The step developed in analyzing the data from the learning device evaluation sheet is to convert the qualitative data into quantitative data by using the Likert scale provisions with categories: very valid (4), valid (3), less valid (2), invalid (1), and scores ranging from 1.75 to 4.00. The

evaluation criteria for the validity of the learning device and test matter are specified in the presentation and calculated using the percentage values formula.

Percentages of qualifying have classifications that are very good, good, fair, and not good, with a ratio range between 1.00 and 100. The data analysis of the STEM-based learning device validity test instrument with the PIRPOSAL model EDP is carried out by calculating the validator and user agreement index using Aiken's V index. Aiken's index has intervals $0 \leq V \leq 0{,}4$ (less), intervals $0{,}4 < V \geq 0{,}8$ (minus), and intervals $0.8 < V \leq 1{,}0$ (valid). The interpretation of the reliability calculation of two validators is calculated with Kappa Cohens.

2.2 Analysis of teacher and Students responses

To analyze the elevation data, students and teachers' responses to worksheet with the PIRPOSAL EDP model based on STEM can be done using the percentage accuracy formula. Percentage of Achievement has qualifications consisting of excellent, good, sufficient, and insufficient, with a rate of achievement ranging from 0% to 100%.

2.3 Analysis of Creative Thinking Skills Based on Indicators

Student creative thinking skills tests between before and after learning were analyzed using N-gain scores. High-category N-gein indices had a gain score of $g \geq 0.70$, medium-sized categories had a score of $0.30 \leq g < 0.70$, and low-categories had g scores of < 0.30.

3 Results and Discussion

3.1 Analysis Stage

The analysis stage is used to obtain information about the need or one that is not needed to develop a STEM-based physics worksheet approach with the PIRPOSAL EDP model to enhance the learners creative thinking skills. What is needed is to analyze the materials used as key information in learning and the availability of materials that support the implementation of learning. Based on interviews with high school physics teacher in Senior High School Banda Aceh, namely: 1) activities during learning are still using conventional methods so that the learning process curriculum 2013 has not been implemented to the maximum; it is in accordance with the statement that the cause of low creative thinking ability in learning physics is generally dominated by lecture methods, where learning tends to be centered on teachers with learning processes of transfer of knowledge [17]; and 2) during the implementation of the learning process, many obstacles are experienced, such as the lack of use of one of the teaching materials, worksheet. for that, teachers need a varied

worksheet in learning to improve creative thinking skills; 3) teachers have never implemented the STEM approach in this senior high school because it feels difficult and there are not yet STEM-based LPDs in senior high school Banda Aceh worksheet, which is commonly used in learning skills that have a simple form. For some of the above reasons, the researchers felt it necessary to develop a STEM-based physics worksheet approach with the PIRPOSAL EDP model to enhance the students creative thinking skills.

The second analysis is a curriculum analysis. This analysis is carried out to formulate indicators and learning objectives based on core competencies and basic competencies that are applicable at Banda Aceh High School. This is done so that the development of learning devices is done in accordance with the conditions of the students. This is the result of the analysis of the student condition based on the results of observations in the field and interviews with one of the teachers of physics in senior high school Banda Aceh, Indonesia: 1) The students have difficulty analyzing and solving questions. In physics, if the questions are different from the examples given by the teacher of the field of study, this is in line with the research that states that the students have difficulties answering questions in physics that measure their creativity. The better the concept the student has, the easier it is to come up with new ideas and develop their creative abilities [18], and the less active the student is in learning. This is seen when the learning process is going on. There are some students who do not pay attention to the teacher's explanation. 3) The students are accustomed to the explanations of the teacher alone, which causes them to be less active in asking questions. So at the time of giving questions with a higher level of difficulty, the student tends to be confused about how to solve the given questions. Based on these observations, students should be more active in learning. This requires a learning device, namely worksheet, that has an approach so that it can motivate pupils more actively and be able to cultivate the learning spirit of students independently with teachers.

3.2 Planning Stage

This stage of planning is the systematic formulation of the worksheet. At this stage, a systematic determination is carried out, which includes the steps of the student's work. There are several components that should be taken into account in the presentation of the worksheet, namely the title of the KPD, the competence to be achieved, the completion time, the equipment or materials required to complete the task, the steps of the work, the tasks to be done, and the reports that must be done. The worksheet developed should contain the inquiry learning model syntax and also conform to the engineering design process syntax as characteristic of the STEM approach. The language used in compiling the worksheet is a simple language that is easy to understand by the students. The color selection is adjusted to attract the attention of the students to the tasks that are available at the worksheet.

3.3 Development stage

This stage serves to see to what extent the already-designed worksheet validity can be used. After obtaining the assessment, the worksheet will be revised according to the

input of the material expert validator, media expert, and linguist. The results of the validation of the experts against the STEM-based learner worksheets with the PIRPOSAL EDP model on physics learning show that the material expert has very valid criteria with a score of 3.42. For validity tests and rehabilitation tests, worksheet products have valid criteria and good reliability with scores of 0.81 and 0.84. Media experts are among the highly valid criteria, with a score of 3.53. For validity tests and rehabilitation tests, worksheet products have valid criteria and good reliability with scores of 0.84 and 0.81, respectively. The linguist was included in the highly valid criteria with a score of 3.70. For validity tests and rehabilitation tests, worksheet products have valid criteria and excellent reliability with scores of 0.90 and 1.00. Based on the data obtained, it shows that STEM-based student worksheets with the PIRPOSAL model EDP on physics learning belong to the category of highly qualified with a total percentage of 88,08%. But there are still shortcomings that need to be fixed. Here's the input and advice from the experts in Table 2.

Table 2. Product improvements according to expert

worksheet Validation Expert	Suggestions/Improvements
Media Expert	Create author name on the WORKSHEET cover section
Material Expert	1. The stimulus has to be fixed 2. Purpose reviewed again 3. Indicators and steps must be clear
Linguist	Create a glossary

Based on Table ii of the recommendation/improvement column, improvements are needed in the WORKSHEET. It aims to improve the quality of the educational material developed. The researchers made improvements to a product that had already been developed based on the input from the experts as presented at Fig. 2, 3, 4, 5, and 6.

Fig. 2. Worksheet before the revised discourse

Fig. 3. Worksheet after the revised discourse

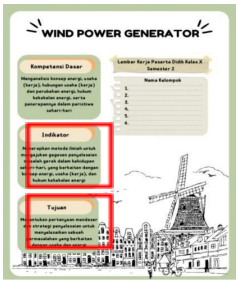

Fig. 4. Worksheet before indicators, objectives and authors revised

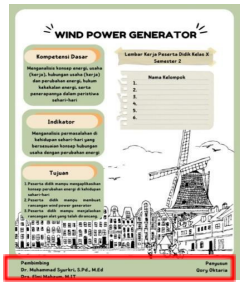

Fig. 5. Worksheet after indicators, objectives and authors revised

Fig. 6. Worksheet after adding the glossary

3.4 **Results of the elevation response of teachers and students**

The result of this response was a teacher's response to STEM-based worksheet with the PIRPOSAL model EDP on the enterprise material and energy developed. The results of the teacher's response calculation obtained a data score with an average percentage of 95.31% belonging to the category of excellent. While the result of the student response is the student's response to STEM-based worksheet with the PIRPOSAL model EDP on the enterprise material and energy developed, The calculation results obtained data scores with an average of 84% belonging to the category excellent. These results indicate that the STEM-based student work sheet with the PIRPOSAL EDP model on enterprise materials and energy received a very practical response from the student.

3.5 Creative thinking skills test results on fluency indicators

To see improvements in creative thinking skills, students learn fluency indicators using N-gain tests comparing pre-test and post-test scores, which can be seen in Table 3 below

Tabel 3. Data on students' creative thinking skills

Test Type	N	Min	Maks	X
Pre-Test	17	33.33	66.67	0.53
Post-Test	17	83.33	100	0.98
	N-gain			0.97
	N-gain %			97%

Based on the data in Table 3, the pre-test average is 0.53. After being given a learning treatment with STEM-based physics worksheet using the EDP step of the PIRPOSAL model, there was a 97% improvement in creative thinking skills with an average post-test score of 0.98, which was in the high improvement category. To facilitate the presentation of data, the researchers also presented it in graphical form (see Fig. 7).

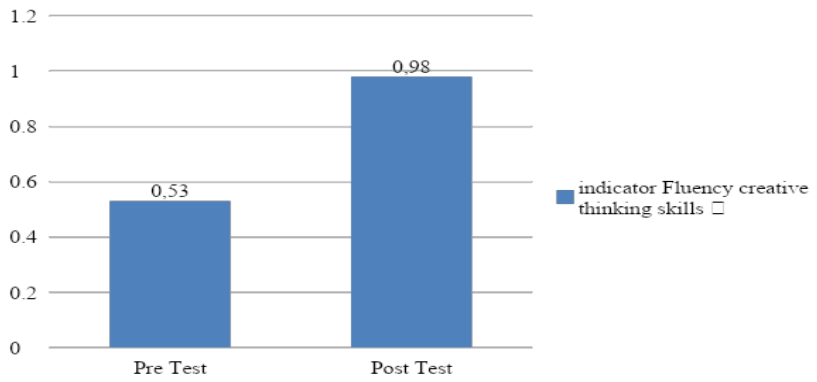

Fig. 7. Students' creative thinking skills data results

Based on Fig. 7, learning results before and after treatment by applying the PIRPOSAL model EDP in a STEM-based physics approach, it is known that on the indicator Fluency, pre-test values obtained a percentage of 53.00% and post-test values of 98.00%, so it can be stated that students can apply the concept of enterprise to applications in everyday life, apply the concepts of kinetic energy, potential energy, and the law of energy conservation to contextual problems in daily life, as well as analyze problems in day-to-day life in accordance with the notion of business

relationship with energy change. The N-gain value obtained on the fluency indicator is high in the category of 0.97 because the student can trigger many ideas, many answers, many problem solvings, and many questions smoothly to complete the product to be created. It is in line with research [19] that a student can be said to meet the fluency indicator if (1) he or she triggers many ideas, many answers, many problem-solving skills, and many questions smoothly; (2) he or she gives many ways or suggestions to do different things; and (3) he or she always thinks of more than one answer. In the learning process using the PIRPOSAL model in STEM-based physics, there is an observation process that will focus on the activity of generating ideas related to the problem. In the worksheet with the stages of the EDP PIRPOSAL model, this stage is called ideation. According to [20], producing ideas is usually a group creativity process that occurs simultaneously to learn about variables that can influence or be influenced by a problem. At this stage, the student's understanding of the physical concepts of everyday life increases so that, if interpreted in a product, the student is able to create a product that functions in daily life according to a given problem.

4 Conclusion

Based on the formulation of the problem and the results in this study, the conclusion obtained is that this research and development produces STEM-based worksheet with EDP PIRPOSAL model on effort and energy material, which has been validated by material, media and language expert lecturers with an average score of 3.55 so that the product is very valid to be used as a learning resource. A STEM-based worksheet with EDP PIRPOSAL model can improve creative thinking skills on fluency indicators in learning with a score of 0.97 and has a high category.

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