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Development of Physics Learning Tools Based on the STEM-Creative Problem Solving Model to Increase Students' Scientific Literacy and Creativity

Ahmad Busyairi[1*], Ahmad Harjono[2], Syahrial[3], Muhammad Taufik[4], Jannatin Ardhuha[5], Yulia Hasan[6]

[1,2,3,4,5,6] Physics Education, University of Mataram, Mataram, Indonesia.

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Corresponding Author:
Ahmad Busyairi
ahmad.busyairi@unram.ac.id

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Abstract: Scientific literacy and creativity are two of several competencies that are very important to have now and in the future. However, referring to the data released by TIMSS and the results of previous research, shows that the scientific literacy and creativity of students in Indonesia are both low. This research aims to develop a STEM-Creative Problem Solving model learning tool to increase students' scientific literacy and creativity. This type of research is research & development. The development procedure in this research uses a 4D mode; define, design, develop, and disseminate. The instrument for knowing expert assessments of learning tools that have been developed uses validation sheets. From the results of the assessment of 3 (three) experts, it shows that the learning tools that have been developed have high validity with an average score for learning plans of 3.83 and an average validity score for student worksheets of 3.81. Thus, it can be concluded that the learning tools that have been developed are suitable to be continued to the limited trial stage (effectiveness test) and disseminated widely.

Keywords: Learning Tools, STEM-Creative Problem Solving, Scientific Literacy, Creativity.

Introduction

Education is an important aspect that can determine the quality of a nation's civilization. Through education, the intellect, attitudes and skills of a nation are trained and developed. The government has made various efforts to improve the quality of education in Indonesia. However, it seems that the quality of education in Indonesia to date has not shown progress in a better direction. This can be seen from data released by TIMSS (Trends in International Mathematics and Science Study) which shows that the learning achievements of students in Indonesia tend to decline from year to year (Simbolon et.al., 2019).

TIMSS is an international educational assessment conducted by the International Association for the Evaluation of Educational Achievement (IEA). The assessments carried out by TIMSS are designed to measure students' understanding of students' mathematical abilities and scientific literacy. According to TIMSS, the future of a nation's civilization can be seen from the extent to which human resources from that country master these two abilities. The mathematical abilities that are the focus of studies conducted by TIMSS are individuals' abilities to understand, interpret, use and participate in various contexts that involve mathematical concepts in everyday life. Meanwhile, scientific literacy includes students' understanding of scientific concepts, basic knowledge of science, data analysis skills, and the ability to analyze and solve scientific problems. In addition, TIMSS also evaluates students' understanding of the scientific process,

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including scientific research methods, hypothesis testing, and experimentation.

Based on TIMSS data from 2007 to 2015, it shows that the mathematics and scientific literacy abilities of students in Indonesia are still very low. TIMSS data for 2007 shows that the average scientific literacy score of Indonesian students is 427 with a ranking of 35 out of 49 countries. The scientific literacy of Indonesian students continues to decline, where in 2011 Indonesia was ranked 40th out of 42 countries with a score of 406, and in 2015 it was ranked 45th out of 48 countries with a score of 397. This data shows that in recent years, Indonesian students rank relatively low in TIMSS measurements, especially in scientific literacy. The average scientific literacy of students is always below the international average score and even tends to decline (Jones & Zanker 2013; Verawati et. al. 2019). This shows that there are problems in the Indonesian education system. Problems can include a curriculum that is less relevant, low quality of learning, and unequal access to education. TIMSS data is one indicator that shows the need for improvement efforts in education in Indonesia to increase student achievement in mathematics and science.

Apart from scientific literacy, one of the skills that must be trained to face the challenges of the 21st century is creativity (Busyairi et. al, 2015). Creativity is important for all professions today. Without creativity, a person will tend to use outdated (old-fashioned) solution ideas to face new challenges or problems even though sometimes these solutions or solutions are no longer appropriate to the situation and conditions (Kusuma, 2010). This is in line with the statement of Clegg, et.al., (2006) which states that creativity is no longer a compliment but has become the main factor that every individual must have in the current era of globalization. Creativity is the key to facing challenges and taking advantage of every opportunity. Creative students are able to create innovative solutions to complex problems. Creativity also allows students to be able to adapt to change, collaborate with others effectively, and communicate in innovative ways. Additionally, creativity empowers individuals to take initiative and develop themselves. In the context of education, encouraging creativity is essential to prepare future generations to be successful and relevant in the era of the Industrial Revolution 4.0.

However, the problem is that based on the results of previous research, students' creativity is still low (Rapika, et.al., 2018; Tayuda, & Siswanto, (2020); Meiarti, 2021). Based on the research results of Busyairi, et.al., (2021), student creativity in Indonesia is still low, especially in the aspects of Originality and Elaboration. Originality is the ability of students to generate unique ideas, ideas, or solutions, think of unusual ways, or be able to make unusual combinations from various elements. Meanwhile, elaboration is the ability of students to produce ideas, concepts, or solutions that are equipped with detailed and interesting reasons and explanations. (Isaksen, 1995; Silver & Edward, 1997; Treffinger et. al., 2006).

The low level of scientific literacy and creativity of students indicates that the quality of education in Indonesia is low. Therefore, innovation is needed in learning that is oriented towards increasing student literacy and creativity. One learning model whose activities support creative thinking activities and are oriented toward increasing students' scientific literacy is STEM-Creative Problem Solving (STEM-CPS) learning. Creative Problem Solving (CPS) is a learning model whose stages are oriented toward a collaborative creative problem-solving process (Isaksen, 1995; Treffinger et.al. 2006; Kandemir et.al. 2009). The main characteristic of the CPS learning model is that it involves integrated divergent (overall) and convergent (concentrated) thinking activities at each learning stage. In CPS, the problems given are real-world problems that are open-ended so that many solutions/answers can emerge (Wang, et.al., 2005; Wang, et.al., 2008). This is what differentiates the CPS model from learning models that are oriented toward other problem-solving processes, especially the Problem Solving (PS) model. In PS, the problem-solving process is strictly regulated and structured which directs students in a closed way to find a solution. A problem-solving process like this will have an impact on the few solutions that students can offer.

STEM-CPS is a form of integrating the CPS learning model with the STEM approach. This means that the STEM-CPS learning process follows the syntax or stages of the CPS learning model by trying to integrate or incorporate elements of Science, technology, engineering, and mathematics (STEM) into several stages. This integration aims to ensure that students not only understand physics concepts conceptually (scientific literacy) but also that students' mathematical abilities and creativity in developing technology are also trained.

Method

The final goal of this research is to develop a STEM-CPS based Physics learning tool on Dynamic Electricity material. The development stage in this research uses the 4-D model (Define, Design, Develop, Disseminate) (Thiagarajan et. al., 1974). The definition or needs analysis stage is carried out through preliminary studies and literature studies which include; front-end analysis, Learner Analysis, task analysis, concept analysis, and specifying instructional objectives. The second stage in the 4D model is design. In this research, there are 2 (two)

main activities carried out; format selection, and initial design. The development stage is the stage for producing a development product. This stage consists of 2 (two) main steps, namely expert appraisal accompanied by revision and developmental testing. However, this research only reached the assessment stage by experts or expert validation.

The data collection instrument is a validation sheet. The validation sheet is used to determine the validity of the learning tools that have been developed. The experts were asked to provide responses in the form of information about whether the instrument that had been prepared had no improvements, had improvements, or could be completely overhauled. The experts involved in this validation were 3 lecturers. The validation data is analyzed by determining the average score of all validators and then interpreted using the following criteria.

Table 1. Validity Criteria for Learning Tools

Score	Category
$3{,}75 < \bar{X} \leq 4{,}00$	Very valid
$2{,}50 < \bar{X} \leq 3{,}75$	Valid
$1{,}75 < \bar{X} \leq 2{,}50$	Invalid
$1{,}00 \leq \bar{X} \leq 1{,}75$	Very invalid

Data on the validity of learning devices was obtained from 3 expert validators originating from. The validation results and suggestions from the validator are then used as a basis for improving the learning tools that have been developed.

Result and Discussion

This research consists of 4 main stages, namely; define, design, develop, and disseminate.

Define

There are 5 (five) activities carried out at this stage, namely; front-end analysis, Learner Analysis, task analysis, concept analysis, and specifying instructional objectives. Front-end analysis is the first step in the process of developing this learning tool. The aim is to understand the context of the problem and identify the reasons behind the development of learning tools. The results of the initial analysis were carried out by examining general problems that occur in schools, especially at the senior secondary school (SMA) level. In this research, initial analysis was carried out by analyzing TIMSS assessment data and research results from previous researchers. The results of the initial analysis show that Indonesian students' scientific literacy is always below the international average and tends to decline from year to year. Apart from that, the results of previous research also show that Indonesian students' creativity is still relatively low. The low level of scientific literacy and creativity of students can be used as a barometer of the low quality of education in Indonesia. Therefore, it is necessary to innovate in the field of education, especially in the learning process. The innovation referred to here is a change in conventional learning towards learning that provides more opportunities for students to develop scientific literacy and student creativity, especially in the technology development process.

The next step is to carry out a Learner Analysis. The aim is to find out the characteristics of students in order to adapt the material, approach, and learning strategies that will be applied. The learning tools that will be developed in this research are intended for upper secondary school level students. Therefore, the level of complexity of the learning content that will be provided is adjusted to the cognitive level of the students.

Researchers also carried out task analysis by analyzing the curriculum by paying attention to Core Competencies (KI) and Basic Competencies (KD) which were used as references for developing learning tools and indicators for achieving learning goals. The KD used is KD 3.1 and KD 4.1 dynamic electrical material. The basic competencies that students must master after learning activities are completed based on KD 3.1 and KD 4.1 are; Analyzing the working principles of unidirectional (DC) electrical equipment and their safety in everyday life and conducting experiments on the working principles of unidirectional (DC) electrical circuits using scientific methods and presenting experimental results.

The next step at this stage is to carry out Concept Analysis. Concept analysis is carried out by conducting an in-depth analysis of the concepts that will be taught in dynamic electricity material. The concepts that students will learn in this dynamic electricity material are; Electric current and resistance, ohm's law, electric circuits, (series, parallel, and mixed), and Khirchoff's law.

After going through the four stages, the next step is Specifying Instructional Objectives. Specifying Instructional Objectives is carried out based on the results of front-end analysis, Learner Analysis, task analysis, and concept analysis. There are two main objectives for developing this learning tool, namely increasing scientific literacy and student creativity. Therefore, the formulation of learning objectives is based on indicators of achieving these two learning objectives.

Design

In this research, there are 2 (two) main activities carried out at the Design stage, namely; format selection (format selection), and initial design (initial design). In

the selection format process, the researcher reviews the literature, especially theories, and concepts that are relevant to the design of the learning tools that will be developed. Researchers also conducted a literature review of the results of related research that had been carried out previously. Based on the results of the preliminary study and literature study, it was found that the learning tool that will be developed is the STEM-CPS Model learning tool. STEM-CPS is a form of integrating the CPS learning model with the STEM approach. This means that the STEM-CPS learning process follows the syntax or stages of the CPS learning model by trying to integrate or incorporate elements of Science, technology, engineering, and mathematics (STEM) into several learning activities. This integration aims to ensure that students not only understand physics concepts conceptually (scientific literacy) but also to improve students' mathematical abilities and creativity, especially in the technology development process.

Birikut is a learning design resulting from integrating the Creative Problem Solving Model with a STEM approach (STEM-CPS).

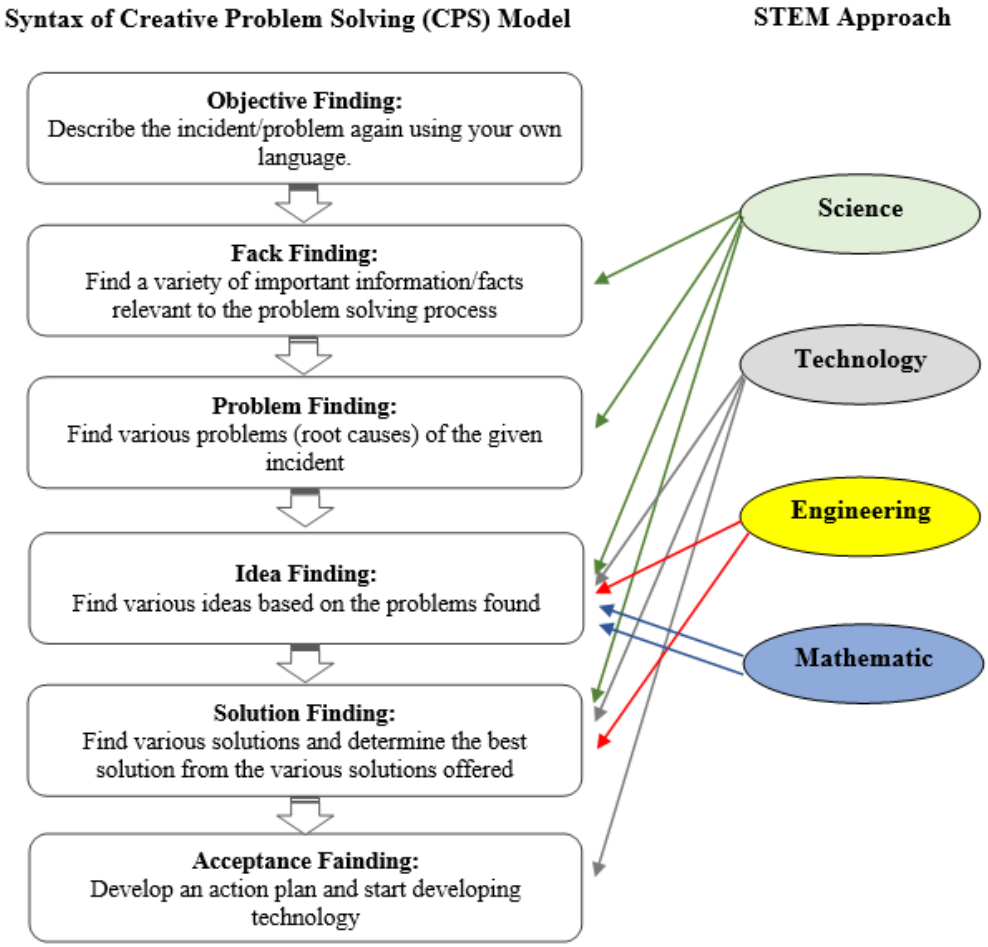

Figure 1. Learning design results from integrating the CPS model with a STEM approach

Figure 1 above is a description of the STEM-CPS learning syntax. This stage is used as a basis for compiling the stages of learning activities in the Learning Plan and Student Worksheets.

Apart from that, at this stage, the researcher also determines the format of the problems that will be solved by students during the learning process in the classroom. Referring to the main characteristics of the CPS learning model, namely that it involves divergent (overall) and convergent (concentrated) thinking activities in an integrated manner at each learning stage. The problem format given is in the form of open-ended real-world problems so that it can allow the emergence of many creative solutions/answers (Wang et. al., 2008).

Develope

The development stage is the main stage of this research. At this stage, researchers began to prepare learning tools consisting of Learning Plan and Student Worksheets based on the previously developed STEM-

CPS learning model design (Figure 1). Apart from that, researchers also develop problems according to the form or format of the problem that has been determined and designed in the previous stage. The following is an example of a problem that will be solved during classroom learning activities by applying the stem-CPS model.

Problem:
Lately, you've often complained about your flashlight battery decreasing in voltage very quickly. Finally, you are planning to replace your flashlight with an LED light which is said to be much more economical. You also buy 12 clear LED lights at the nearest electronics shop to use to replace your flashlight bulb which has a capacity of 6 batteries with each battery having a voltage of 1.5 volts. After trying to replace your flashlight with an LED lamp, it turns out that the LED lamp you are using is damaged. You think there is something wrong with all this. You also see that the LED lamp packaging says 20mA/3V, which means that the LED lamp will quickly be damaged if it is supplied with a current exceeding 20 mA and a voltage exceeding 3 V. Because you feel challenged, you plan to carry out an experiment to investigate and find a solution to this problem.

OBJECTIVE FINDING
Describe the incident above in your own words!
……
……

FACK FINDING
What information is important to note from the incident above? Explain what you know about this information in relation to the concept of electricity!

No	Information	Explanation
1		
2		

PROBLEM FINDING
Determine what problems you find so that you need to find a solution! Why do you guys think that?

No	Problem	Explanation
1		
2		

IDEA FINDING:
To answer the problem you have formulated, carry out the following experiment.

SOLUTION FINDING:
From the ideas you have listed, determine the solutions you can provide! Why do you answer that?

No	Solution	Explanation
1		
2		

ACCEPTANCE FAINDING
From the solutions that you have registered, sort in detail how you will realize these solutions.?
Make the solution you have offered come true in the form of a simple technology project!

Figure 2. Description of learning activities in student worksheets based on the STEM-CPS model

Apart from compiling or creating learning tools, at this stage, an expert appraisal is also carried out. An expert appraisal is carried out to determine the validity of the learning tools that have been developed. The experts involved in this validation were 3 lecturers, namely; Dr. Muh. Makhrus, M.Pd., Dr. Hikmawati, M.Pd., and Drs. Sutrio, M.Sc. The results of the validation of learning tools by 3 experts are shown in the following table.

Table 2. Learning Plan Validation Results

No	Assessment Aspects	Average
1.	Clarity of Learning Plan Identity	4,00
2.	Suitability of learning indicators with KI and KD	4,00
3.	The formulation of indicators uses operational verbs	3,67
4.	Conformity of learning objectives with indicators	4,00
5.	Suitability of teaching materials in the lesson plan with learning objectives	4,00
6.	Suitability of teaching materials with time allocation	3,67
7.	Suitability of time allocation for each learning stage	3,67
8.	Suitability of learning stages with the STEM-CPS model	4,00
9.	Suitability of learning content and activities with learning objectives	3,67
10.	Suitability of learning resources to the curriculum and learning objectives	4,00
11.	Simplicity of sentence structure in lesson plans	3,67
12.	Use of standard language and according to EYD in the Learning Plan	3,67
	Average	**3,83**

The data in Table 2 above shows that the average score for the 3 (three) validation assessments of the Learning Plan is 3.83. This average score shows that the Learning Plan that has been developed is in the very valid category.

Table 3. Validation results of Student Worksheets

No	Assessment Aspects	Average
1.	Clarity of Student Worksheets Identity	4,00
2.	Clarity of instructions for working on Student Worksheets	4,00
3.	Suitability of the problem form with the characteristics of the STEM-CPS Model	3,67
4.	Problems are presented using language that is easy to understand	3,33
5.	The systematics or sequence of activities/activities in the Student Worksheets are arranged in a structured and systematic manner	4,00
6.	Suitability of the activities/activities in the Student Worksheets with the stages of the STEM-CPS Model	4,00
7.	Clarity of instructions, statements and questions in the Student Worksheets	3,67
8.	Clarity of illustrations and pictures in the Student Worksheets	4,00
9.	The level of relevance of the activities in the Student Worksheets to the learning objective	4,00
10.	The level of relevance of the questions in the Student Worksheets to the learning objectives	3,67
11.	Use of language that is clear and easy to understand	3,67
	Average	**3,81**

The data in Table 3 above shows that the average score for the 3 (three) validation assessments of Student Worksheets is 3.81. This average score shows that the Student Worksheet that has been developed is in the very valid category with slight improvements, namely simplifying the level of complexity of the problems used on the grounds that the quality of students due to the COVID-19 pandemic is low.

Conclusion

The research results show that learning tools based on the STEM-CPS model have a very valid category with slight improvements. Thus, it can be concluded that the learning tools that have been developed are suitable for continuing to the limited trial (effectiveness test) and dissemination stages.

In this research, the material used is limited to dynamic electrical material. Therefore, it is recommended for future researchers to develop learning tools on other materials. Apart from that, researchers

also suggest that the learning tools that have been developed be continued to the limited trial and wider trial stages so that the products resulting from this research can be disseminated and used in schools..

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