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Cite as: AIP Conference Proceedings **2330**, 050008 (2021); https://doi.org/10.1063/5.0043259
Published Online: 02 March 2021

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Improvement of Students' Creative Thinking Skills in Optical Subject with STEM Worksheets

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Abstract. Creative thinking skills are a major challenge in education today. Students with good creative thinking skills can certainly compete in the global era. Creative thinking skills need to be trained through STEM learning. This research is focused on improving high school students' creative thinking skills in the optical instrument topic through the development of STEM worksheets. The developed worksheet provides students with experiences designing, creating projects, making videos, uploading assignments, analyzing projects, and discussions. The varied valuable experiences with integrating technology and engineering in learning are advantages of the worksheets developed. These experiences have not been provided in previous worksheets. ADDIE design with five stages is used as a design in worksheet development. Three experts validated the development results; after being declared valid, the readability level was tested on 15 students. The worksheet is implemented in one class with the one-group pretest-posttest design used to measure the practicality and effectiveness of the worksheet. The t-test was used to analyze the differences in creative thinking skills before and after learning physics using a STEM worksheet. The results showed a significant difference in students' creative thinking skills before and after experiencing learning using worksheets developed. The improvement also showed form N-Gain score of 0.16. In conclusion, the results of the STEM integrated worksheet are valid, practical used, and effective for improving students' creative thinking skills. The development of STEM worksheets on different materials needs to be considered.

INTRODUCTION

Creative thinking skills are one of the 21st-century skills essential for students (1,2). This skill is very important for students because it can be used as a competency both in the school environment and in the community (3). One of the ways to adapt to the demands of today's changing is through creative thinking (4). However, several reports showed that the creative thinking skills possessed by students were still relatively low (5), including students in Indonesia (6,7).

Creative thinking is the ability to find and convey various ideas and ways to solve problems with existing physical symptoms so that students become active in learning. There are four components in creative thinking, namely: (1) thinking fluently (fluency) or making various ideas, (2) thinking flexibly (flexibility) or producing ideas, answers, varied questions, and being able to see a problem from a different point of view, (3) thinking original (originality) or giving birth to ideas, new and unique expressions, (4) elaboration or building something from other ideas (8,9). Currently, students' creative thinking skills around the world are still at a low level, not exception Indonesian students (10,11). The report showed that the scientific creativity of these students was low because students found it difficult to understand the concepts learned in school, especially on abstract topics such as optical instruments (12). Therefore, to facilitate the understanding of these abstract concepts, it is necessary to provide learning that provides real or direct experience to students (13), including the making of teaching materials such as worksheets.

The 4th International Conference on Mathematics and Science Education (ICoMSE) 2020
AIP Conf. Proc. 2330, 050008-1–050008-7; https://doi.org/10.1063/5.0043259
Published by AIP Publishing. 978-0-7354-4074-6/$30.00

Several worksheets development studies have been conducted. For example, a study conducted by Choo *et al.* (14) presents a worksheet as a scaffold in PBL learning; and found that the worksheet did not significantly improve student competence. Another study was conducted by Karsli and Sahin (15) by developing worksheets for student-teacher candidates; This worksheet was developed based on the science process skill indicator. A similar study was also reported by Krisdiana *et al.* (16) by developing math worksheets. However, this study does not specify how the framework and foundation were used in developing the worksheet.

Although several researchers have carried out worksheet development, this current study was different. First, the worksheet developed is intended for use in a STEM environment. Second, this worksheet is also intended to develop students' creative thinking skills. Third, the development of this worksheet follows strict and systematic guidelines. In schools, teachers must develop worksheets as teaching materials for students in meeting the demands of basic competencies, including the development of students' skills. The development of this instrument will certainly be more effective and efficient when considering the existing framework or guidelines. This study follows a worksheet development guide from the Indonesian government (17), which consist of three components, namely: 1) educational and dialogical learning activities that lead to 21st-century skills or known as 4C, namely, Critical Thinking and Problem-Solving Skills, Communication Skills, Creativity and Innovation, and Collaboration, as well as the growth of HOTS or high-order thinking skills and character, 2) utilize learning technology following the concepts and principles of Technological Pedagogical Content Knowledge (TPACK), 3) guided by Basic Competencies, using a level of thinking starting from analysis (C4), evaluation (C5) and creation (C6) so that it is applied.

STEM is a form of student-centered constructivism theory that teaches technology and engineering using science and mathematics (18). Learning with STEM aims to teach the material in a meaningful way through the systematic integration of knowledge, concepts, and skills (19). Merging can be done from only two disciplines or with the four disciplines, science, technology, engineering, and mathematics, into one class, unit, or lesson based on the relationship between subjects and real-world problems (20). The integration of technology in learning will be optimal if it can make learning more meaningful (21) and help students reason deeply (22). Technological Pedagogical Content Knowledge (TPACK) is a framework that integrates technological knowledge, pedagogy, and content to make it easier for teachers to develop teaching strategies and facilitate student understanding (23). Purwaningsih *et al.* (24) stated that TPACK could improve prospective teachers' ability to plan and implement lessons using technology.

Based on the problems that have been described, it is necessary to develop a worksheet that can correct the deficiencies of the existing optical instruments worksheet. Using the TPACK framework and the STEM approach seems to have the potential to promote students' creative thinking skills. This study aims to develop valid, effective, and practical worksheets in improving students' creative thinking skills.

METHOD

This research was conducted in Malang, East Java, Indonesia, with respondents from class XI MIPA high school students in the 2018-2019 school year. This research is included in Research and Development (R&D), using the ADDIE design, whose steps consist of Analysis, Design, Development, Implementation, and Evaluation (25). Evaluation is carried out at each stage as a formative evaluation and carried out thoroughly after implementation as a summative evaluation. The details of the activities are shown in Figure 1.

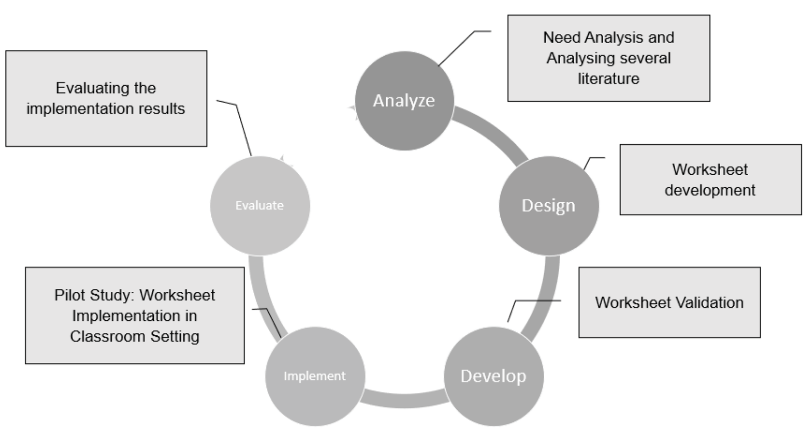

FIGURE 1. The flow of worksheet development with ADDIE design

At the analysis stage, a literature study is carried out, namely looking for references related to the problems studied, literature about worksheets, creative thinking, PjBL, STEM, TPACK. After that, a google form gathered opinions from several physics teachers whose schools hold Sistem Kredit Semester (SKS)-one of the best education systems in Indonesia where students are given the freedom to determine their learning load (not all schools apply it). This SKS is then organized into study learning units known as Unit Kegiatan Belajar Mandiri (UKBM). The reason why we chose this type of school is based on the results of the initial study. Our preliminary studies showed that students and teachers who use the system needed worksheets supporting programmed independent learning. Prepare interview guides for some of the physics teachers and questionnaires. Questionnaires for students, among others, ask about the content, benefits, convenience, and difficulties of using worksheets. Based on the results of the initial survey analyzed and mapped the strengths and weaknesses of the existing worksheets, the optical instruments worksheet was designed to correct the shortcomings of the existing worksheets. The worksheets developed are in the form of books for students and equipped with learning guides for teachers.

At the design stage, learning tools were developed. Prepare lesson plans based on indicators derived from basic competencies standard, the steps of the activities follow the PjBL model syntax, and each step was integrated with STEM components. Worksheets were developed based on activities in the lesson plans. The instruments developed included: an instrument for assessing the ability to think creatively and its rubric, an instrument for validating learning tools, and a learning observation sheet. At the development stage, all learning tools were validated by experts, namely one physics lecturer and two high school physics teachers. After being validated, revisions were made according to the validator's suggestions. The readability of the worksheet was tested on 15 senior high school students in Malang who had studied optical instruments. At the implementation stage, learning is carried out by implementing the worksheet that has been declared valid. School facilities are not optimal, but there is the internet, and many students have cellphones. Learning is carried out in one class consist of 20 students. The experimental design used one group pretest and posttest design (26). In the formative evaluation stage, evaluation is carried out to see the work of the worksheet. A summative evaluation is carried out after implementation in the field. The results of the evaluation can be used in the next implementation.

In particular, the data in this study were obtained based on the results of the pretest, posttest, and observation. Pretest and posttest were carried out to measure students' creative thinking skills before and after the implementation of learning using a worksheet developed. The pretest and posttest score data were analyzed using the t-test with a 0.05 significance value. The test was continued by calculating the N-Gain to determine the increase in creative thinking skills. These results indicate the effectiveness of the developed learning tools. During the learning process, observations are made to observe the suitability of the learning plan developed with its implementation, to show the planned learning implementation. Besides that, students also observed activities and activeness during learning. Observation data were analyzed using percentages. The results of this validity test showed the practicality and effectiveness of the learning tools being developed.

RESULTS AND DISCUSSION

By a systematic process, we developed the STEM worksheet. The components of the worksheet consist of, 1) cover containing the title and identity of the author, 2) worksheet identity, 3) concept map, 4) objectives/indicators, 5) instructions for using student books, 6) check prerequisite ability, 7) pre-preparation stage, 8) preparation for the project stage, 9) planning for the project, 10) project implementation, 11) post-project stage 12) assessment and evaluation. The teaching guide contains lesson plans, videos of phenomena, project examples, answer keys, and assessment rubrics. Lesson plans are developed based on basic competencies in the curriculum, and then these basic competencies are translated into indicators and learning objectives. The learning steps are following the PjBL syntax by integrating STEM and TPACK components.

Learning begins with a video of a phenomenon related to the material. After that, Students discussed a problem that will be sought for a solution through project assignments. Student books are not packaged purely as modules, but some sections are done together classically, and some assignments must be done independently. Schoology is used as a means of communication between teachers and students outside face-to-face hours, for example, to provide reading material and assignments that must be done by students, uploading student work, discussions.

The time provided for learning optical instrument material is 12 lesson hours consisting of 6 meetings, each meeting 90 minutes. Optical instrument material is divided into four sub-materials, namely, 1) concave and convex mirrors, 2) eyes, cameras, and loops, 3) microscopes, 4) binoculars. Four sub-materials are designed to make only two products, namely the periscope, to apply the principle of reflection to the mirror and binoculars as a form of applying the principle of refraction to the lens.

The validity of the worksheet is determined from the results of the validity of its components from experts. The validity of the teacher guide consists of lesson plans. Each component is determined based on the content and constructs validity. The results of the average content and construct validity are shown in Table 1.

TABLE 1. Result of the average validity test of the three validators

No	Component	Content Validity		Construct Validity	
		Score	Criteria	Score	Criteria
1	Teacher's Guide Lesson plan	3.8	Very valid	3.6	Very valid
2	WORKSHEET				
	Concept map	3.7	Very valid	3.6	Very valid
	Purpose/Indicator	3.4	Very valid	3.5	Very valid
	Prior knowledge diagnosis	3.5	Very valid	3.7	Very valid
	Pre-preparation stage	3.6	Very valid	3.6	Very valid
	Preparation for the project	3.6	Very valid	3.6	Very valid
	Stage	3.7	Very valid	3.6	Very valid
	Project implementation	3.5	Very valid	3.6	Very valid
	Post-project stage	3.7	Very valid	3.6	Very valid
	Assessment and evaluation	3.4	Very valid	3.5	Very valid
3	Learning observation sheet	3.6	Very valid	3.7	Very valid
4	Students response sheet	3.8	Very valid	3.6	Very valid
5	The creative thinking skills test	3.5	Very valid	3.5	Very valid

The validity of the optical worksheet shows all components of the content and construct validity are very valid, as shown in Table 1. Some suggestions from the validators have been corrected, among others: inconsistency in using the terms students or students and adding written instructions for using Schoology. Overall, the assessment of the feasibility of the optical instrument worksheet developed was declared very valid. The evaluation of the three validators in the learning observation sheet, Student Response Sheet, and Creative thinking skills test was declared very valid. There are suggestions for improvements in the assessment rubric and corrected in the creative thinking assessment questions. The assessment of the readability level of the optical worksheet by 15 high school students showed that the average student agrees that the worksheet is interesting to study. It can increase the enthusiasm for learning, helps make it easier to understand the material, can be studied independently, the language is easy to understand, the material presented is coherent, and emphasizes important concepts. On the consistency of fonts and font sizes that received poor ratings.

Overall, the optical worksheet and teacher's guide can be declared very valid to be tested empirically, which is implemented in one particular class to see its practicality and effectiveness. The summary of the average observation results from two observers who observed the activities of the teacher and students at six meetings, grouped into the preliminary, core, and closing activities, is shown in Table 2.

TABLE 2. Recapitulation of learning implementation assessment results in terms of teacher and students activities

Stages	1st and 2nd meeting		3rd meeting		4th meeting		5th and 6th meeting	
	Teacher	student	Teacher	student	Teacher	student	Teacher	student
preliminary	3.25	3.00	3.50	3.50	3.25	3.00	3.50	3.25
Core activities	3.20	3.00	3.11	3.00	3.44	3.33	3.22	3.11
Closing	3.00	3.00	3.00	3.00	4.00	3.00	3.00	3.00
Sum	18.45		19.11		20.02		19.08	
Total	76.87		79.62		83.41		79.50	
Criteria	suitable		suitable		very suitable		suitable	

Table 2 shows the results of observations related to the implementation of learning. Observations were made from preliminary to closing. As a result, six meetings went well with the categories suitable and very suitable. These results indicate that the worksheet developed can be used practically.

The results of the assessment showed that each lesson is carried out following the previously prepared design. This result is reinforced by the absence of significant obstacles faced by the teacher during learning. Student responses during learning were obtained from the results of questionnaires and observations; the results showed that on average, 80.05%

of students said that learning with the optical worksheet was fun and could understand. The results of the questionnaire included: not being depressed, being able to understand the material, not being burdened by tasks, being happy to have challenging activities, having activities to be creative, and not just doing questions. By the opinion of Bybee (18) and Han et al. (27), giving challenging assignments, and students can channel their creativity through project assignments to make products. Besides, students feel happy learning, do not feel tense so that teachers can easily teach important concepts (28). The teacher also feels that learning takes place casually and is not tiring. The use of Schoology provides access to teachers and students for presentations as well as a means to collect assignments, practice questions. It is a learning resource media that can be accessed anytime and anywhere (29). The results of the implementation of the worksheet in this class indicate that the optical worksheet can be implemented properly.

Effectiveness was measured by comparing the results of the pretest with the results of the students' posttest using the one-group pretest-posttest design, which was tested using the t-test. The results showed a significant difference between students' creative thinking skills before and after learning using the STEM worksheet ($t=9.93$, $p<0.05$). Then, the pretest-posttest result data was also tested by using N-Gain. It can be seen that there is a statistically significant increase in the ability to think creatively from the pretest to posttest scores. The highest increase in the fluency indicator is to produce a lot of answers or ideas. Flexibility shows that the answers given are different from various points of view. Originality shows the ability to think and answer independently. Elaboration builds ideas based on other ideas. The results of the pretest and posttest for each indicator are shown in Table 3.

TABLE 3. Pretest and posttest result of creative thinking ability on each indicator

No	Indicator of Creative Thinking Ability	Question Number	Average	
			Pretest	posttest
1	Fluency	4	2.35	4.30
2	Flexibility	5	1.90	3.30
3	Originality	6	2.05	2.50
4	Elaboration	1,2,3	1.70	3.10

Based on Table 3, it can be seen that there is an improvement in the ability to think creatively from the pretest to posttest scores. The increase in the fluency indicator was 1.95 points. This indicator was measured by evaluating the number of relevant ideas expressed by students in solving problems in the worksheet and answering the questions given (30). The increase in this indicator shows that students can generate many answers or ideas to solve a problem. The flexibility indicator increased by 1.4 points. This shows that the answers given by students are different in terms of various points of view. The originality indicator increased by 0.45 points. This indicator is measured based on the authenticity of the thoughts shown by students in solving problems. The results of this increase indicate that students can think and can answer given problems independently. The elaboration indicator increased by 1.4 points. This indicator is measured based on the students' ability to develop ideas in planning and doing projects, explaining the relationship between the optical instrument concept and the resulting project, expanding ideas, and analyzing experimental data. The results of the improvement in this elaboration indicator show that students can build ideas based on other ideas. This is because solving a problem requires a combination of ideas that produce not only unique ideas but also have true values. So that with the increase in each indicator of students' creative thinking abilities, it shows that students can generate many ideas, produce strategies in solving problems, present their thinking results, develop and link an idea, and create something new in solving problems (31). Meanwhile, when viewed from the normalized gain score, it showed an average N-gain of 0.16 and included a low increase. This category is based on the criteria for improving creative thinking skills, according to Mellenbergh (32). So, it can be said that learning using a worksheet that is developed is effective in improving students' creative thinking skills.

The advantages and specifications of the optical instruments worksheet developed are: 1) meeting the achievements of optical instruments, 2) designed to improve students' creative thinking skills according to one of the 21st-century skills, 3) applying the integrated STEM-PjBL model, giving experience for students to design and create projects and 4) utilize technology to video project implementation, using Schoology to facilitate communication between teachers and students outside of face-to-face hours which is adjusted to the principles of the TPACK framework. The worksheet developed is in the form of student books and learning guides for teachers, which have been tested for validity, practicality, and effectiveness. Thus, the worksheet developed is different from the worksheet that is already in circulation. Worksheets were developed to equip students with valuable experiences, designing, making simple equipment, using technology to face the challenges of the 21st century and the 4.0 industrial revolution.

Students' creative thinking skills in this study can increase because at each stage of STEM integrated learning; students are encouraged to participate in the learning process (13). Students are trained to apply their knowledge in solving problems and making products in the form of optical instruments according to the stages on the worksheet. Students' ability to solve problems, think in detail, and reflectively can motivate students to practice and improve their creative thinking skills. Besides, students 'thinking abilities will increase because STEM allows students not only to know or understand science but also to develop students' abilities to see situations from new and creative perspectives and express concepts and information clearly (33).

CONCLUSION

The STEM worksheet developed in student books and teacher guides in teaching has been declared valid, practice, and effective in improving students' creative thinking skills. The worksheet was declared valid in terms of content and construct, practical with a percentage of 80.05% done. The STEM worksheet was also effective for improving students' creative thinking skills. There are differences in students' thinking skills scores before and after using the STEM worksheet ($t=9.93$, $p<0.05$). Furthermore, the increase in creative thinking skills has increased with an average N-gain value of 0.16, increasing in the low category.

There are some limitations to this study. For example, the product being developed is only tested in a limited manner, so a wider trial is needed to determine the results' consistency. Another limitation is this research is only limited to the material of optical instruments. The last worksheet implementation is carried out in schools with limited facilities and student abilities. If implemented in schools with adequate facilities and good student motivation, it may produce different results. The research can be continued by implementing this study's results on a more diverse range of student characteristics. Furthermore, studies can be continued by developing a similar structure in other materials.

ACKNOWLEDGMENT

This research is supported by Universitas Negeri Malang with 2019 PNBP funds. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the manuscript.

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