THE EFFECT OF STEAM APPROACH DIGITAL TEACHING MATERIALS ON INCREASING CREATIVE PROBLEM-SOLVING SKILLS

Irma DHITASARIFA

ORCID: 0009-0003-9761-6337
Faculty of Mathematics and Natural Sciences
Universitas Negeri Semarang
Semarang, INDONESIA

Indah Urwatin WUSQO

ORCID: 0000-0002-4582-2214
Faculty of Mathematics and Natural Sciences
Universitas Negeri Semarang
Semarang, INDONESIA

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ABSTRACT

This study aims to determine the effect of using STEAM digital teaching materials on increasing creative problem-solving skills. This study has a quasi-experimental research design with a nonequivalent control group. This study employed a random sampling technique and obtained Class 8-F as the experimental class and Class 8-H as the control class. Data were collected using documentation, tests, and questionnaires. The data analysis carried out was a homogeneity test, normality test, t-test, n-gain test, and analysis of students' responses. According to this study, it can be concluded that there is an effect of STEAM digital teaching materials to increase creative problem-solving skills. The t-test results indicate a significant difference in students' average creative problem-solving skills in the experimental and control classes. The effect of STEAM digital teaching materials is proven by an increase in creative problem-solving skills, which are analyzed using N-gain, resulting in the high category (0.73) for the experimental class with STEAM digital teaching materials and the medium category (0.50) for the control class after using STEAM digital teaching materials.

Keywords: STEAM, Digital teaching materials, Creative problem-solving skills.

INTRODUCTION

Science and technology in the 21st century are developing rapidly, so many countries are improving the quality of various sectors, including education. The development of science and technology requires students to be innovative and have the skills to survive and thrive in an increasingly complex life (Zubaidah, 2019). These skills that students must have are known as 21st-century skills. 21st-century skills include problem-solving, critical thinking, communication, collaboration, and creativity (Zubaidah, 2016). The 21st century requires students to have problem-solving, creative thinking, and communication skills. In the current era of globalization, students need creativity in solving problems because it can help students create a framework of thinking that is neatly arranged in solving complex problems.

Creative problem-solving skills emphasize reaching an alternative idea in the problem-solving process (Isrok'atun, 2012). Phaksunchai et al. (2014) concluded that creative problem-solving skills help students deal with and solve problems using new methods that are more effective and appropriate for each situation. Isrok'atun (2012) suggests that creative problem-solving consists of several indicators: (1) objective-finding, (2) fact-finding, (3) problem-finding, (4) idea-finding, (5) solution-finding, and (6) acceptance-finding. Creative problem-solving uses more profound thinking than the average level of thinking and focuses on finding unique ideas.

The results of preliminary observations and interviews with science teachers at SMP Negeri 1 Purwodadi show that students' creative problem-solving indicators are still low. When the teacher presents a problem, most students cannot provide the right solution. This situation shows students' inability to think divergently and convergently. Data on the final odd semester assessment show that only 25-35% of students score above the passing grade. The learning resources at SMP Negeri 1 Purwodadi are textbooks and teaching materials by the teacher. They have dense content and lack supporting figures to attract students' interest and motivation in learning. Applying appropriate learning resources and models will make learning more effective and flexible, so it is hoped that it can improve students' creative problem-solving skills.

Teaching material is a subject matter arranged systematically for teachers to use and for students to achieve learning objectives. Teaching materials must be arranged interestingly and systematically, including learning material, methods, and evaluation (Gomez-Pablos et al., 2017). Isrok'atun (2012) concluded that teaching materials can improve creative problem-solving skills by understanding the material and exploring problem-solving skills more creatively.

STEAM can be interpreted as "education to improve students" through interest in and understanding scientific technology to foster STEAM literacy. STEAM education combines the arts in STEM to increase student engagement, problem-solving skills, creativity, and innovation (Colucci-Gray et al., 2017; Thuneberg et al., 2018). Miller et al. (2019) concluded that learning with a STEAM approach makes students more appreciative of combining science and art with various forms of creativity, critical thinking, and imagination skills when students try to understand various existing problems.

Several studies regarding STEAM's influence on creativity and problem-solving skills have been conducted separately (Perignat & Katz-Buonincontro, 2019; Erol et al., 2023; Quigley et al., 2017). According to Irwandani et al. (2017), teaching materials make students learn independently and make it easier to understand the material. One of the ways to use teaching materials to improve creative problem-solving skills is through learning with a STEAM approach so that students better understand material from various scientific disciplines. Integrating several scientific disciplines helps students better analyze, collect information, and solve problems that are interconnected with other problems. The integration of all aspects of STEAM can make the learning process more meaningful (Asmuniv, 2015).

Lee et al. (2017) researched creative problem-solving skills as steps in activities in the STEAM learning approach, but there has been no research on the influence of STEAM digital teaching materials on creative problem-solving skills in science learning. This study used digital teaching materials with a STEAM approach on light and optical devices for eighth-grade junior high schools. STEAM digital teaching materials are innovations in presenting material in an electronic format containing five STEAM elements: science, technology, engineering, art, and mathematics. STEAM is a development of STEM by adding elements of art so that in the learning process, it can develop students' creativity by creating a fun learning tool. Digital teaching materials with a STEAM approach will help students better understand the material studied by linking it to various disciplines. Digital teaching materials will later be uploaded to Google Classroom. Using Google Classroom can make it easier for teachers to manage learning and accurately deliver information to students (Hardiyana, 2015). Iftakhar (2016) states that Google Classroom has several advantages. It saves time, is easy to use, flexible, cloud-based, and free.

Based on these problems regarding students' low creative problem-solving, STEAM digital teaching material is necessary for research. This study aims to determine the effect of using STEAM digital teaching materials on increasing creative problem-solving skills.

METHOD

Research Design

This study has a quasi-experimental research design with a nonequivalent control group. The research design is presented in Figure 1.

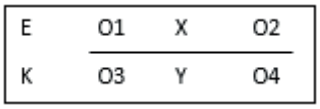

Figure 1. Research Design (Sugiyono, 2018)

Information:

X: Treatment using STEAM digital teaching materials

Y: Treatment using science books from school

O1: Experimental class before treatment

O2: Experimental class after treatment with STEAM digital teaching materials

O3: Control class before treatment

O4: Control class after treatment with science books from school

Participants

This study employed a random sampling technique. The homogeneity test obtained the classes as the research samples: Class 8-F as the experimental class and Class 8-H as the control class.

Data Collection and Analysis

Data were collected using documentation, tests, and questionnaires. The questionnaire method is used to find out students' responses to using STEAM digital teaching materials. The test method is to determine students' creative problem-solving skills. The data analysis carried out was a homogeneity test, normality test, t-test, n-gain test, and analysis of students' responses. The results of the t_{count} of the t-test were compared to t_{table} with a significance level of 5%. H_0 rejection criteria is if $t_{count} \geq t_{table}$ (Sugiyono, 2018). Meanwhile, for the N-gain analysis, the categories are listed in Table 1.

Table 1. Category of N-gain (Hake, 1999)

Range	Category
$g < 0,3$	Low
$0,3 \leq g < 0,7$	Medium
$g \geq 0,7$	High

FINDINGS

This study aims to measure the differences in use caused by applying STEAM digital teaching materials to increase creative problem-solving skills. STEAM digital teaching materials have an effect if there are differences in the experimental class's creative problem-solving skills, which are better than the control class.

The difference was tested using STEAM digital teaching materials on light and optical devices to increase creative problem-solving skills, using the average difference test in the control and experimental classes. The calculation results are presented in Table 1

Table 2. The Difference of Mean Score Test between Experimental and Control Classes

Group	N	Dk	t_{table}	t_{count}	Criteria
Experiment Control	32	62	1,999	8,047	H_0 is rejected

Table 2 shows that $t_{count} > t_{table}$ so that H_1 is accepted; that is, there is a significant difference in the average increase in creative problem-solving skills in the control and experimental classes. This difference is inseparable from appropriate learning models and resources when teaching and learning activities occur. In line, Widayoko et al. (2018) argued that the results of the t-test showed that learning in the control and experimental classes had significant differences in improvement, so the use of learning models and resources can affect the improvement of students' learning outcomes. The difference in the increase in creative problem-solving skills is affected by teaching materials in learning. The results of the n-gain test are analyzed to determine which teaching materials can increase creative problem-solving skills.

The increase in creative problem-solving skills from the beginning to the end of the meeting was analyzed using N-gain. The increase in creative problem-solving skills is presented in Table 3.

Table 3. The Increase of Creative Problem-Solving Skills

Data	Experiment		Control	
	Pretest	Posttest	Pretest	Posttest
Average	47,65	85,31	41,64	70,70
N-Gain	0,73 (High)		0,50 (Moderate)	

Table 3 shows that the experimental class's creative problem-solving skills are higher than the control class. The N-gain of the experimental class is 0.73 in the high category, while the control class is 0.50 in the medium category (Hake, 1999).

The N-gain results show that the experimental class that uses STEAM digital teaching materials has a higher increase in creative problem-solving skills than the control class that uses science textbooks. This result is under Ko & Hong (2018), who state that learning by applying the STEAM approach has a positive effect on significantly increasing students' creative problem-solving skills.

The analysis results of the increase in the average of each creative problem-solving skill indicator in the experimental and control classes were obtained from the test with ten questions of six indicators of creative problem-solving skills. The complete analysis results are displayed in Figure 2.

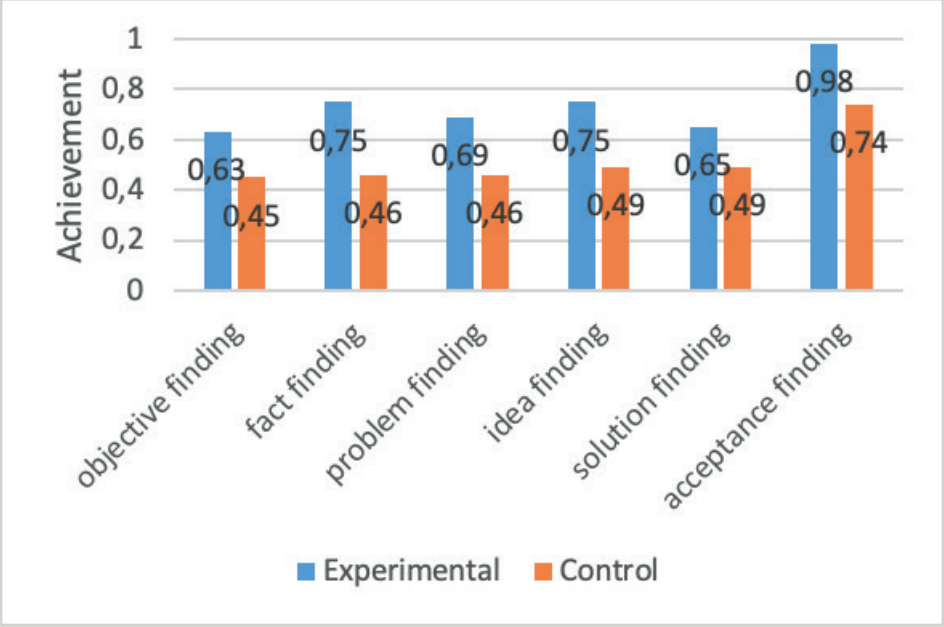

Figure 2. Average Increase of Each Creative Problem-Solving Skill Indicator

Figure 2 shows that the average increase for each creative problem-solving skill indicator in the experimental class is better than that of the control class. The highest average increase for each indicator was found in the sixth indicator, the acceptance finding. The results were 0.98 and 0.74, with the experimental class being better than the control class. The indicator with the lowest average increase, the objective finding, showed that the experimental and control classes were almost equal, but the control class was slightly better than the experimental class. The increase in the control class was 0.63, while the experimental class was 0.45.

DISCUSSIONS AND CONCLUSION

Creative problem-solving skills combine creativity or an idea with elements of novelty and uniqueness from the person who created it and a problem or a situation that presents a problem to solve (Isrok'atun & Tiurlina, 2014). Therefore, creative problem-solving is solving a problem through creative or renewable ideas. According to Isrok'atun (2012), creative problem-solving skills emphasize reaching an alternative idea in a problem-solving process. Creative problem-solving is used to identify problems and plan a solution.

The learning model also affects the increase in students' creative problem-solving skills. STEAM is one of the learning tools that can help students develop creative problem-solving skills. STEAM learning is contextual learning that invites students to understand the phenomena around them better so that students can better explore their abilities (Yakman & Lee, 2012). Through STEAM learning, students can also build their understanding and knowledge through creating a project (Mu'minah, 2020). STEAM education aims to teach students to apply the main content and practice each STEAM discipline in all situations students face (Bybee, 2013).

The learning process in this study used the PjBL learning model with the STEAM approach. The PjBL-STEAM model positively impacts students, especially developing soft skills (Anindya & Wusqo, 2020). The learning process has several stages, starting with essential questions. Students were given a problem related to light and optical devices through STEAM digital teaching materials and videos through PowerPoint. This stage trains students' creative problem-solving skills on indicators of objective-finding, fact-finding, and problem-finding in digital teaching materials in the science exploration sub-chapter and videos displayed via PowerPoint. Objective-finding indicators were created when the teacher presented a problem and students re-described it using their language. After this, students were invited to understand the goals for solving problems from the studied material.

Starting with the essential question stage also trains students in fact-finding indicators when they observe problems in the video in the Observing sub-chapter or things in their surroundings related to light and optical devices. After that, students determined the facts of the matter. Other results from this observation can train students in problem-finding indicators, where students formulate essential questions based on their observed problems. Students used these questions to determine the problems to be solved through a project. This statement is reinforced by Cunningham's opinion in Sengul and Katranci (2015), which states that students must thoroughly understand the subject/situation in problem-finding activities.

In the design project stage, students made a project design and collected various information needed to make the project in the Understanding sub-chapter, complying with the instructions from the teacher. At this stage, it can be seen how active students are in finding and gathering information from various relevant learning sources. This stage also trains students' idea-finding indicators, where students' activeness is apparent when students start exploring ideas or ideas to solve problems, and then students have to re-analyze the ideas they have designed. Solving some problems can be done by formulating new ideas and strategies that are more innovative (Nuzliah, 2015).

Creating the schedule stage emphasizes the engineering field in the project creation, as contained in the Counting sub-chapter on STEAM digital teaching materials. Students made a schedule for doing a project by preparing the tools and materials needed following the design that had been made. At this stage, students practiced the solution-finding indicators. Students thought of the best solutions from their creative ideas, as in the Creative sub-chapter in the previous idea-finding stage.

The next stage is monitoring the students and the project's progress. Students asked questions about project assignments they had not understood, presented project developments, and explained the relationship

between light and optical devices in the project. At this stage, students were trained in idea-finding and acceptance-finding. Students presented the project's progress and analyzed the relationship between light and optical devices. This statement is reinforced by Polya's opinion in Phonapichat et al. (2014), who reveals that one of the creative mathematical problem-solving processes is to develop a settlement plan. This stage trains acceptance-finding indicators where students describe the steps for answers based on the determined concepts/formulas.

The last stage is assessing the outcomes and evaluating the experience. Students and the teacher evaluated the project's results by linking the STEAM elements and expressing their experiences when working on the project. At this stage, students practiced the acceptance-finding indicator. Experimental class students better understand the relationship between STEAM in learning and projects because the examples and applications are listed and explained in STEAM digital teaching materials. Control class students still do not understand the relationship between STEAM material and approaches to learning and projects.

Rahmazatullaili et al. (2017) stated that project-based learning allows students to solve problems through creative thinking and interactions that lead to actual problem-solving. This study uses the PjBL learning model with the STEAM approach, which is applied to both classes by applying different learning resources and PhET simulations to support the learning process so that creative problem-solving skills in both classes increase equally. PhET simulation was carried out on reflection and refraction of light because students can directly conduct experiments to find concepts. In line with Riantoni et al. (2019), using PhET simulations in learning can help students learn new topics, build concepts or skills, and strengthen ideas. However, the increase in creative problem-solving skills in the experimental class using STEAM digital teaching materials is higher than in the control class using science textbooks. This STEAM learning can be applied through teaching materials designed based on STEAM characteristics so that students develop creative problem-solving skills. The teacher's task here is to act as a motivator and facilitator. Teaching materials allow students to formulate problems, provide arguments, and evaluate problems (Rosida et al., 2017).

The current condition of distance learning requires digital learning media that can be used independently, such as digital teaching materials (Sunarti & Rusilowati, 2020). Digital teaching materials can help students understand material during distance learning activities. Teaching materials with pictures and videos also make students more active and not easily bored when learning. Lawe et al. (2021) argued that digital teaching materials do not bore students in the learning process because they contain elements of text, images, and videos that are more interesting to students. The results of this study are also supported by Manurung (2020), who states that using digital teaching materials provided by teachers can increase students' attention and transfer knowledge and understanding of the material well so that students' learning outcomes increase.

STEAM digital teaching materials also contain text, images, and video to facilitate distance learning. In line with Minarni et al. (2019), using visual media by combining images and text can be more fun, engaging, and meaningful, increasing students' curiosity about what will be learned. Visual media with pictures and colors can facilitate students' understanding, strengthen memory, and foster interest in learning. STEAM digital teaching materials can enhance students' creative problem-solving skills because they contain STEAM aspects, which can train creative problem-solving skills at each stage of learning. STEAM digital teaching materials contain a summary of material that can help students learn more efficiently and contain pictures and videos that can help broaden students' horizons. The summary of the material in the teaching materials is arranged in several STEAM aspect sub-chapters. The increase in creative problem-solving skills is divided into six indicators, which are analyzed as the highest and lowest increases.

The acceptance-finding indicator has the highest average increase compared to other indicators, with 0.98 in the experimental class. The increase in this indicator occurred due to the effect of the treatment from STEAM digital teaching materials, which increased students' creative thinking skills. Without STEAM digital teaching materials, the results of an increase in the control class using the science books from school were only 0.74. Acceptance-finding is the stage where possible sources of assistance are considered, potential implementation steps are identified, the most promising solutions are focused and prepared for action, and specific plans are formulated to implement solutions (Isrok'atun et al., 2018). STEAM digital teaching materials affect the increase in acceptance-finding through the Counting sub-chapter, which contains the application of formulas in learning materials. This sub-chapter contains mathematics aspects.

Students also filled in mini-proposals already available on STEAM digital teaching materials to be presented at the last meeting by linking them to light and optical devices and the STEAM approach in the project. In addition to presenting the project's results, students shared their experiences working on it. The objective-finding indicator obtained the lowest average increase among other indicators, with 0.63 in the experimental class. In the objective-finding stage, students identify and explain general descriptions of the phenomena described and shown (Nuraziza & Suwarma, 2018). Students were then invited to understand the goals for solving problems from the study material.

The low objective finding in the experimental class is because the digital teaching materials do not yet fully contain the goals and objectives of each meeting. Therefore, students find it difficult to relate the goals of the problem-solving process to the problems given, so the average increase obtained is lower than that of other indicators. The increase in the average objective finding in the control class was 0.45 because students did not understand the events presented by the teacher, so they could not correctly determine the purpose of solving the problem.

The role of STEAM digital teaching materials that still need to be improved is achieving the objective-finding indicator. Rahman (2011) argued that students' low learning outcomes can occur due to the lack of optimal learning media and resources due to disturbances in their application, such as misinterpretation and lack of attention. Students pay less attention because of the monotonous material delivery or focus more on other things outside of learning. Disturbances of misinterpretation occur due to the formation of an inaccurate perception of an object, a symptom, or an event (Rahman, 2011).

The results of this study are also supported by Isrok'atun (2012), who states that teaching materials are very effective in assisting the learning process to improve students' creative problem-solving skills, as evidenced by the increased pretest and posttest results. In line with McCrum (2017), using teaching materials effectively increases creative problem-solving skills through problem-based interdisciplinary. This study utilizes teaching materials in the technology field, and students can access teaching materials with computers or smartphones. This teaching material applies the STEAM approach, making the learning process more meaningful and allowing students to integrate learning in various disciplines (Asmuniv, 2015).

Students' responses to STEAM digital teaching materials is 80.63% in the good category, which exhibits the effect of using teaching materials in the difference in the average assessment results in the experimental and control classes. Students' positive responses follow Fidiantara et al. (2020), who stated that teaching materials can encourage students' interest and motivation in teaching and learning classroom activities. Herawati and Muhtadi (2018) also argued that electronic teaching materials can increase students' attention to materials and make learning more persuasive. Learning involving students' direct participation will be more effective and efficient because they will find real experiences independently and explore their abilities, making learning more enjoyable. Fun learning will increase the motivation of students to take part in learning.

Most students stated that learning with STEAM digital teaching materials made them more active and happier in participating in learning activities because learning became fun, and they understood the material more easily. Project-making activities in STEAM digital teaching materials can also foster creative problem-solving skills because students face problems that must be solved. STEAM digital teaching materials are uploaded to Google Classroom, which students can access at any time. This response shows that STEAM digital teaching materials are suitable for use in learning activities and can be an alternative that can be applied in schools.

According to this study, it can be concluded that there is an effect of STEAM digital teaching materials to increase creative problem-solving skills. The t-test results indicate a significant difference in students' average creative problem-solving skills in the experimental and control classes. The effect of STEAM digital teaching materials is proven by an increase in creative problem-solving skills, which are analyzed using N-gain, resulting in the high category (0.73) for the experimental class with STEAM digital teaching materials and the medium category (0.50) for the control class after using STEAM digital teaching materials.

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BIODATA and CONTACT ADDRESSES of AUTHORS

Irma DHITASARIFA graduated from the Science Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, in 2021. She also completed a professional teacher education at Universitas Negeri Semarang in 2022. Now, she is a junior high school science teacher at SMP 1 Purwodadi, Central Java, Indonesia. She is also interested in educational entrepreneurship and owns a GSM after-school program. Her current address is Grobogan, Central Java, Indonesia.

Irma DHITASARIFA
Science Education Study Program, Faculty of Mathematics and Natural Sciences
Address: Universitas Negeri Semarang, 50299, Semarang, Indonesia
Phone: +6288232450081
E-mail: irmadhita18@gmail.com

Indah Urwatin WUSQO is a doctoral student in the Educational Research and Evaluation Study Program at the Graduate School of Universitas Negeri Yogyakarta. She is an Assistant Professor in the Science Education Study Program at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. Her academic interests are science teaching and learning, assessment in education, and using media/computers in education. She has four journal articles published in international indexes and other national and international articles. She has nine papers submitted to international meetings with international indexes and other national conferences.

Indah Urwatin WUSQO
Doctoral student of Educational Research and Evaluation Study Program,
Address: Graduate School of Universitas Negeri Yogyakarta, 55281, Sleman, Indonesia
Phone: +6285643577698
E-mail: indahurwatin.2021@student.uny.ac.id

Science Education Study Program, Faculty of Mathematics and Natural Sciences
Address: Universitas Negeri Semarang, 50299, Semarang, Indonesia
Phone: +6285643577698
E-mail: urwatin@mail.unnes.ac.id

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