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Research Article

Copper Tape- Solar Cell-Based Electrical Circuit as STEM Learning Media to Improve Science Literacy and Creative Thinking Skills

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ABSTRACT

By 2022, the ranking of Indonesian students' science literacy skills will improve from 70th to 64th, but the latest score is lower than before. In this research, the researchers use a mixed-methods embedded design. This study aims to describe the implementation and improvement of science and creative thinking skills in students following the introduction of a solar cell project in STEM learning using copper tape solar cells. The research sample consists of 40 junior high school students from a single experimental group. The data collection instruments include a pretest and a posttest to measure science literacy and creative thinking skills, as well as assessment rubrics to evaluate students' creativity. Implementing STEM copper tape-solar cell learning can improve students' science literacy skills, with an average n-gain of 0.4 in the medium category. Implementing STEM copper tape-solar cell learning can improve students' creative thinking skills, with an average n-gain of 0.5 in the medium category. Based on the MANOVA test, the provision of the STEM copper tape solar cell learning model as a whole can have a significant effect on science literacy, increased science literacy, creative thinking, and improved thinking.

1. INTRODUCTION

As science and technology continue to advance, a comprehensive understanding of science is required. In this regard, many students still struggle to grasp scientific concepts in depth and apply them in daily life (National Research Council, 2012).

According to the 2022 Global Creativity Index released by the World Intellectual Property Organization (WIPO), Indonesia ranks 75th out of 132 countries in creative thinking skills, with a score of 27.90. This is an improvement of 12 positions from 2021 (Javier, 2023). However, Indonesia still ranks relatively low in creative thinking skills compared to other Southeast Asian countries, such as Singapore. Research on Indonesian students' creative thinking skills conducted by Madyani et al. (2020) and Saputri & Syukri (2020) also indicates that these skills are generally categorized as low.

The evaluation results from the Programme for International Student Assessment (PISA), recorded by the OECD in the 2018 survey, show that Indonesian students' PISA scores are unsatisfactory. Indonesian students' science literacy is ranked 70th out of 78 countries (Harususilo, 2018). This indicates that science literacy among Indonesian students is relatively low (Adawiyah & Chastanti, 2023; Az et al., 2023; Hartono et al., 2023; Nuryanti et al., 2023; Sartika et al., 2018; Yusmar & Fadilah, 2023). This certainly requires a solution, as we know from the words of Allah SWT in the Quran, Surah Al-Mujadilah, Ayat 11:

يَٰٓأَيُّهَا ٱلَّذِينَ ءَامَنُوٓا۟ إِذَا قِيلَ لَكُمْ تَفَسَّحُوا۟ فِى ٱلْمَجَٰلِسِ فَٱفْسَحُوا۟ يَفْسَحِ ٱللَّهُ لَكُمْ ۖ وَإِذَا قِيلَ ٱنشُزُوا۟ فَٱنشُزُوا۟ يَرْفَعِ ٱللَّهُ ٱلَّذِينَ ءَامَنُوا۟ مِنكُمْ وَٱلَّذِينَ أُوتُوا۟ ٱلْعِلْمَ دَرَجَٰتٍ ۚ وَٱللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ

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> *O you who have believed, when it is said to you, 'Make room in the assemblies,' then make room; Allah will make room for you. Moreover, when it is said, 'Rise,' then rise; Allah will raise those who have believed among you and those who have been given knowledge, by degrees. Moreover, Allah is Knowing of what you do.*

Based on the research conducted, creating miniature home electrical installations or house plans typically involves materials such as light bulbs, power outlets, wires, and batteries as the energy source. The researchers are interested in creating a similar product that uses copper tape instead of electrical wires and an alternative energy source, namely solar cells. The use of copper tape as an electrical conductor in education is still relatively rare, as is the use of solar cells as an alternative energy source. In light of these considerations, the researchers intend to conduct a study titled "Copper Tape-Solar Cell-Based Electrical Circuit as STEM Learning Media to Improve Science Literacy and Creative Thinking Skills of Students," to be conducted at a private school in Jakarta.

2. RESEARCH METHODS

2.1 Research Methods and Design

This research discusses copper tape-solar cell-based electrical circuits as STEM learning media to improve science literacy and creative thinking skills of junior high school students, using the Embedded Design mixed-methods research method. It combines quantitative and qualitative data collection and analysis within a single study to address a problem (Cresswell & Clark, 2014). Quantitative research methods in this study are used to determine improvements in students' science literacy and creative thinking skills after STEM copper tape-solar cell learning, as well as the extent of STEM copper tape-solar cell learning's influence on these skills.

2.2 Data Collection

The data collection techniques in this study combine science literacy questions, creative thinking skills, student activity sheets, and products. The data collection techniques in this study combine science literacy questions, creative thinking skills, learner activity sheets, and products. Science literacy questions are used to measure students' science literacy and creative thinking skills. In contrast, the learner activity sheet is used to assess students' achievements after applying STEM copper tape-solar cell learning. Making a product is the result of learning to solve the problems given by the teacher. Then, the results of students' products are analyzed to measure students' creativity.

2.3 Participant

This study was conducted in one of the private junior high schools (SMP) in Jakarta. The population in this study was all students in grades VII, VIII, and IX in the 2023/2024 school year. Each level (batch) consists of 2 (two) classes, namely female-only and male-only classes. The research sample consisted of ninth-grade students. Sampling was conducted using a purposive sampling technique, with the sample comprising students who had learned about static electricity.

2.4 Measures

2.4.1 Science Literacy skill questions

This science literacy questionnaire was given before and after STEM copper tape-solar cell learning. The science literacy questions developed address the competency aspect, with indicators based on PISA 2018, namely: explain phenomena scientifically, evaluate and design scientific investigations, and interpret evidence and data scientifically. The improvement in students' science literacy was analyzed by comparing pretest and posttest scores for STEM copper-tape solar-cell learning. The value was then analyzed using the N-gain equation. The improvement in students' science literacy skills was analyzed by comparing pretest and posttest scores for STEM copper tape-solar cell learning. The value was then analyzed using the N-gain equation.

2.4.2 Creative Thinking Skills Question

This creative thinking skills questionnaire was given before and after STEM copper tape-solar cell learning. The indicators of creative thinking skills used are based on Torrance (1978) and include fluency, flexibility, originality, and elaboration. The improvement in students' creative thinking skills was analyzed by comparing pretest and posttest scores in STEM copper tape-solar cell learning. The value was then analyzed using the N-gain equation. The improvement in students' creative thinking skills was analyzed by comparing pretest and posttest scores in STEM copper tape-solar cell learning. The value was then analyzed using the N-gain equation.

3. RESULTS AND DISCUSSIONS

The results and findings of the study were analyzed qualitatively and quantitatively to obtain an overview of: The improvement of students' science literacy skills after STEM Copper Tape-Solar Cell learning, the improvement of students' creative thinking skills after STEM Copper Tape-Solar Cell learning, and the effect of STEM Copper Tape-Solar Cell learning on science literacy and its improvement and creative thinking skills and its improvement.

3.1. The improvement of students' science literacy skills after STEM Copper Tape-Solar Cell learning

In this section, data on students' science literacy skills are presented, along with their analysis and discussion. The results of the descriptive statistical analysis of learner science literacy ability data are presented in Table 1.

Table 1. Results of Science Literacy Data Analysis

Data	Pretest	Posttest
Total number of students	40	40
Highest score	43	83
Lowest score	4	30
Average	25.33	51.40
Standard Deviation	9.927	14.62
Cohen's d test	0.21	

Table 1 shows the results of the statistical analysis of pretest and posttest data on students' science literacy skills. The average pretest score in students' science literacy is 25.33 points lower than the average posttest score of 51.40, a difference that is not too large. On the pretest, the highest score was 43 and the lowest score was 4. On the posttest, the highest score increased to 83, and the lowest score increased to 30. This shows that the increase occurred not only in the average score but also in the overall distribution of scores. The standard deviation of the pretest scores was also lower than the posttest scores (9.927 < 14.622). This increase in standard deviation indicates greater variation in learners' science literacy after STEM copper-tape solar-cell learning.

After observing the difference, the Cohen's d effect size test was conducted to determine the extent of STEM copper tape-solar cell learning's impact on students' science literacy skills. Cohen's d effect size test yields a value of 0.21, which is low. It can be concluded that STEM copper tape-solar cell learning has a positive impact on students' science literacy skills in a small category. This means there is a minimal increase in students' science literacy skills before and after STEM copper-tape solar cell learning.

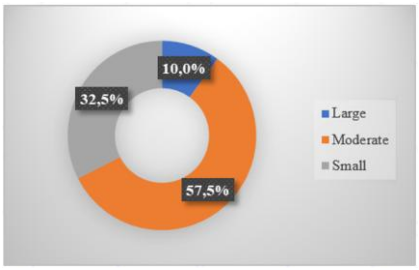


Figure 1. N-gain Categorization of Science Literacy Ability.

Figure 1 shows that only 10% of students were in the high-science-literacy improvement category. This indicates that only a small proportion of learners showed significant improvement in their science understanding after STEM copper-tape solar-cell learning. Most students (57.5%) were in the moderate improvement category. This indicates that the majority of learners experienced a moderate increase in understanding, which is a positive outcome of the STEM copper tape-solar cell learning. A total of 32.5% of students were in the low improvement category. This shows that almost a third of the learners did not experience significant improvement in their science understanding, suggesting the possibility that the STEM copper tape-solar cell learning was not fully effective for this group.

Comprehensively, scientific concepts in dynamic electricity are often considered difficult by students due to their abstract nature and the need for practical activities to improve understanding (Deta et al., 2023). Other research indicates that 33.5% of students experience misconceptions at a moderate level, 29.5% have not yet understood the concepts, and 35% have grasped the concepts (Nawanda De Gupita et al., 2022). Students also struggle to identify relevant physics concepts and equations when solving numerical problems, which affects their problem-solving abilities (Harikrishnaprabu & Annapooranam, 2019). Difficulties in dynamic electricity can also be linked to inadequate student engagement in the learning process, hindering their understanding of electrical concepts

(Hermawati, 2022). Inadequate handling of these learning difficulties can result in low student achievement, including poor science literacy skills.

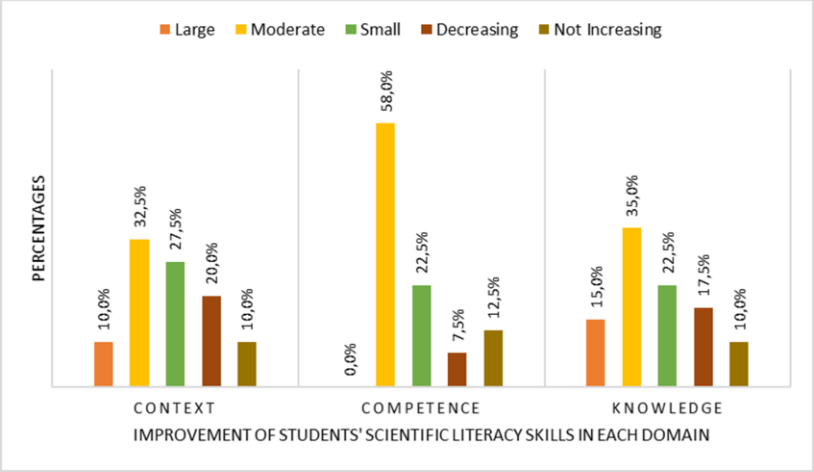


Figure 2. Improving scientific literacy skills in each domain

Figure 2 shows that in the context domain, 10% of learners increased to the high category, 32% to the medium category, 27.5% to the low category, decreased by 20%, and did not increase by 10%. In the competency domain, learners who increased to the high category were 0%; those who increased to the medium category were 58%; those who increased to the low category were 22.5%; those who decreased by 7.5%; and those who did not increase were 12.5%. In the knowledge domain, there were high increases of 15%, medium increases of 35%, low increases of 22.5%, decreases of 17.5%, and no increase of 10%. From the data analysis, it can be concluded that the STEM copper tape-solar cell learning provided shows quite good results, especially in improving participants' science competence. However, there is still room for improvement, especially in the knowledge and content domains, where many learners have neither increased nor decreased.

3.2. The improvement of students' creative thinking skills after STEM Copper Tape-Solar Cell learning

In this section, data on students' creative thinking skills are presented, along with their analysis and discussion. The results of the descriptive statistical analysis of students' creative thinking skills data are presented in Table 2.

Table 2. Data Analysis Results: Creative thinking skills

Data	Pretest	Posttest
Total number of students	40	40
Highest score	43	100
Lowest score	0	33
Average	7.38	53.18
Standard Deviation	2.122	1.576
Cohen's d test	2.45	

The mean pretest score for students' creative thinking skills was 7.38, and the posttest score was 53.18, indicating an increase in students' creative thinking skills after STEM copper tape-solar cell learning. This increase shows that STEM copper tape-solar cell learning is efficacious in improving creative thinking skills. The pretest standard deviation (2.122) was higher than the posttest standard deviation (1.576), indicating that students' posttest scores were more consistent. Cohen's d value of 2.450 indicates a significant effect of the learning intervention on improving students' creative thinking skills. According to Cohen (1988), a d value of 0.8 or higher is considered a significant effect. The data shows that the applied STEM copper tape-solar cell learning has successfully improved students' creative thinking skills. The increase in the posttest mean score relative to the pretest shows this. The high Cohen's d value also indicates that STEM copper tape-solar cell learning significantly improves creative thinking skills.

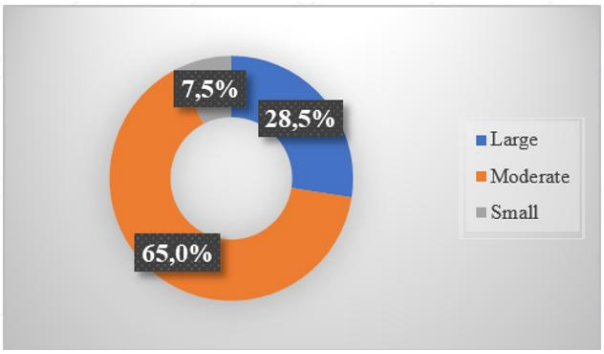


Figure 3. N-gain Categorization of Creative Thinking Skills.

Figure 3 shows that the majority of students (65.0%) were in the low N-gain category. This indicates that most students experienced minimal improvement in their creative thinking skills after learning about copper tape-solar cells. A total of 28.5% of students were in the moderate N-gain category, indicating that almost one-third of students experienced moderate improvement. Only 7.5% of students were in the high N-gain category, indicating that very few students experienced a significant improvement in their creative thinking skills.

Effective strategies are needed to enhance students' learning outcomes and creative experiences. To develop higher-order thinking, Daskolia et al. (2012) recommend that teachers create opportunities for students to engage in learning that involves questioning, criticizing, verifying work, and arguing with each other, all stemming from the students' creative processes. Student motivation is divided into two types: intrinsic and extrinsic. The student's environment heavily influences extrinsic motivation, whereas intrinsic motivation is the primary source of students' creativity (Tang et al., 2020; Yang & Hsu, 2020).

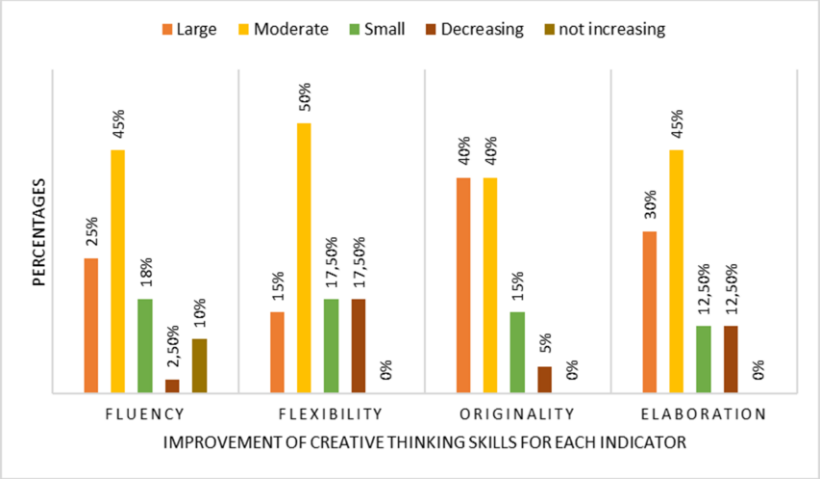


Figure 4. N-gain Categorization of Creative Thinking Skills: Each Aspect

Based on Figure 4, the creative thinking skills of students in the fluency aspect, with the acquisition of a high category, increased by 25%; a medium category, by 45%; a low category, by 18%; and did not increase by 10%. In the flexibility aspect, the number of students who increased was 15%; those in the medium category were 50%; those in the low category decreased by 17.5%; and those in the did not increase category were 0%. In terms of originality, students in the high and medium categories increased by 40%, those in the low category decreased by 5%, and those in the 0% category did not increase. In the aspect of elaboration, students in the high category increased by 30%, students in the medium category increased by 45%, students in the low category decreased by 21.5%, and students in the category that did not increase remained the same.

The above facts reveal that the solar cell project in the STEM Copper Tape-Solar Cell learning can enhance students' creative thinking skills by fostering fluency, flexibility, elaboration, and originality (Wahyuni, et. al. 2024).. The experience of problem-solving and designing practical activities using their own ideas can increase students' interest in science, raise awareness of the importance of connecting scientific activities with real life, problem-solving, creative thinking, and improve effective communication (Gasper & Gardner, 2013). Learning activities through direct observation encourage the emergence of motivation to become a creative individual (Balakrishnan, 2022). The characteristics of creativity include uniqueness and originality in seeking solutions that may be implementable (Rao et al., 2022).

3.3. The effect of STEM Copper Tape-Solar Cell learning on science literacy, its improvement, and creative thinking skills.

Multivariate Analysis of Covariance (MANOVA) was used to evaluate the effect of the Copper Tape-Solar Cell learning model on science literacy, its improvement, and creative thinking skills. The independent variable is STEM learning, whose values are obtained from the LKPD for each STEM aspect. Discussion and presentation are co-variables used in this study. The results of the MANOVA (Multivariate Analysis of Variance) analysis are shown in Table 3.

Table 3. MANOVA (Multivariate Analysis of Variance) results per variable

Independent Variable	Dependent Variable	df	F	sig.	η_p^2	Interpretation
Discussion (co-variable)	ΔLS	1	2.467	.126^{ns}	-	-
	ΔKBK	1	.094	.761^{ns}	-	-
	LS	1	3.240	.081^{ns}	-	-
	KBK	1	3.293	.079^{ns}	-	-
	Product	1	3.251	.081^{ns}	-	-
Presentation (Co-variable)	ΔLS	1	.110	.742^{ns}	-	-
	ΔKBK	1	3.732	.062^{ns}	-	-
	LS	1	.841	.366^{ns}	-	-
	KBK	1	1.716	.200^{ns}	-	-
	Product	1	8.280	.007**	.206	
STEM	ΔLS	5	3.234	.018*	.336	
	ΔKBK	5	3.400	.014*	.347	
	LS	5	2.102	.091^{ns}	-	-
	KBK	5	3.018	.320	.320	
	Product	5	13.743	.682	.682	

Table 3 shows that discussion, as a co-variable, is not significant for any of the dependent variables. That is, the discussion did not show a significant influence on all dependent variables tested. The next co-variable (presentation) showed a highly significant influence on the product ($p < 0.01$) with a large effect size ($\eta p^2 = 0.206$), but was not significant for the other dependent variables. The following variable, STEM learning, showed a significant influence on increasing science literacy and creative thinking skills, with a high effect size ($\eta p^2 > 0.3$). STEM also showed a highly significant influence on Product, with a very high effect size ($\eta p^2 = 0.682$), but was not significant for science literacy.

4. CONCLUSION

Implementing STEM copper tape-solar cell learning can improve students' science literacy skills, with an average n-gain of 0.4 in the medium category. Implementing STEM copper tape-solar cell learning can improve students' creative thinking skills, with an average n-gain of 0.5 in the medium category. Based on the MANOVA test, the provision of the STEM copper tape solar cell learning model as a whole can have a significant effect on science literacy, increased science literacy, and improved thinking skills.

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