ISSN (PRINT) : 2549-9955 ISSN (ONLINE): 2549-9963
JURNAL ILMIAH PENDIDIKAN FISIKA
https://ppjp.ulm.ac.id/journals/index.php/jipf/index

STEM Quartet to Improve Creative Thinking Skills (CreaTS) for High School Students in Physics Learning

Julia Maysarah Rosha[1], Arif Hidayat[1*], and Andi Suhandi[2]
[1] Center for Excellence of Lesson and Learning Studies, Physics Education Department
Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Magister of Physics Education, Faculty of Mathematics and Natural Science
Universitas Pendidikan Indonesia, Bandung, Indonesia
*arifhidayat@upi.edu

Abstract

This study aims to improve high school students' creative thinking skills (CreaTS) in physics learning by applying the STEM Quartet. This study used an experimental design with the pre-experimental method, and the design used was a one-group pretest-posttest design. The population in this study were all students of class X at a high school in Bandung. The sampling technique in this study was purposive. The sample for this research is 16 students aged 15 to 16 years. The instrument in this study was the CreaTSIT (Creative Thinking Skill Instrument Test) in the form of an essay consisting of 20 items. Data were analyzed using the gain score, Wilcoxon signed rank test, stacking, and racking. The results showed a significant difference between the pretest and posttest scores with a p-value of 0.00 and an increase in creative thinking skills (CreaTS) in each indicator with an N-Gain value of 0.67 in the medium category. The four aspects of creation experienced increases, changes in the difficulty level of items, and changes in students' creative thinking skills, as shown through stacking and racking analysis. This study suggests that applying the STEM Quartet can be used as an alternative to improve students' creative thinking skills (creaTS) and can contribute to the world of Indonesian education, especially for physics teachers and physics education researchers.

Keywords: Creative thinking skill; STEM Quartet; Stacking and Racking

Received: 30 July 2023
Accepted: 6 November 2023
Published: 30 December 2023
DOI : https://doi.org/10.20527/jipf.v7i3.9696

How to cite: Rosha, J. M., Hidayat, A., & Suhandi, A. (2023). STEM quartet to improve creative thinking skills (CreaTS) for high school students in physics learning. *Jurnal Ilmiah Pendidikan Fisika*, *7*(3), 435-447.

INTRODUCTION

In the 21st century, rapid development has been seen in various fields of science and technology. In connection with this rapid development in the age of globalization, the quality of human resources must face challenges, either directly or indirectly. Quality human resources require quality education. Therefore, improving the quality of education is an important factor in the success and progress of the country's construction. The role of technology, including education, has been explored (Istiyono et al., 2020; Khoiri et al., 2019; Saprudin et al., 2019).

Physics is a part of science that becomes the basis for the progress of science and technology. Physics is "a way of thinking, a way of investigating, a body of knowledge, and science and its interactions with technology and society". So physics has become an important learning need in schools (Habibi et al., 2020; Istiyono et al., 2020; Malik, Nuraeni, et al., 2019). Physics learning has abstract concepts that require a high and creative level of thinking. So, it takes skills to solve complex problems in learning physics. Therefore, thinking creatively is an important competency in learning physics (Malik, Nuraeni, et al., 2019; Muchsin & Mariati, 2020; Putranta & Supahar, 2019).

Creative thinking and creative skills are increasingly used to find solutions to problems affecting the progress and survival of mankind (Batlona et al., 2019; Malik, Nuraeni, et al., 2019; Prima, 2021). Creative thinking is the ability to use the structure of thought to create something new that is characterized by adding flexibility, credibility, and quantity to students. Students' creative thinking skills have measurable levels and scores. Improving creative thinking means increasing student scores in problem-solving and flexibility (Sahida & Zarvianti, 2019; Zarvianti & Sahida, 2020). Therefore, an effort must be made to improve creative thinking skills by regularly practicing solving a physical problem in life. Unlike those that already exist, creative thinking skills are the ability to create something new, either in the form of an idea or in the form of actual work. Evaluate or measure a student's Students' creative thinking skills are based on indicators of four factors of creative thinking skills: fluency, flexibility, originality, and elaboration (Pratiwi et al., 2019; Sahida & Zarvianti, 2019; Zarvianti & Sahida, 2020).

Several studies reveal that some high schools in Indonesia have not brought into full play the creative thinking capacity of students and have not trained students to solve problems in many forms. As a result, the ability to reason and think logically is underdeveloped, and the ability to think creatively is low. Based on the survey results, students cannot express more than one idea when answering questions about how to solve a certain problem in learning; it is difficult to generate many ideas, interpret images, and give different points of a good academic theory and conclusion (Meiarti, 2019; Saregar et al., 2021; Zarvianti & Sahida, 2020).

Many studies on creative thinking skills through the application of different models and methods have been conducted, including research conducted (Amelia et al., 2021; Darman, 2021; Habibi et al., 2020; Julfitri et al., 2020; Khoiri et al., 2019; Malik, Denya Agustina, et al., 2019; Malik, Nuraeni, et al., 2019; Muchsin & Mariati, 2020; Neolaka & Corebima, 2018; Pratiwi et al., 2019; Ramdani et al., 2021; Saregar et al., 2021; Wartono et al., 2018).

Based on previous studies, it can be seen that in the 21st century, the development of creative thinking skills in students is very important given the requirements of the times. Students must be able to analyze and solve problems by contributing creative ideas as solutions to problems that exist in everyday life. The importance of developing creative thinking skills led some of the above studies to examine the influence of certain applications of learning models and methods used to document the quality improvement process. Learning so that the results of student's creative thinking skills are also expected (Putri et al., 2019; Satriawan et al., 2019; Witdiya et al., 2023)

An approach to learning that teachers can develop to enhance creative thinking is the STEM Quartet framework. In education, STEM (Science, Technology, Engineering, and Mathematics) is a "platform" that integrates science, technology, engineering, and math into learning. STEM learning helps students solve problems, and new students conclude learning by applying it through science, technology, engineering, and mathematics (Kelley, 2016; Sagala et al., 2019; Sokolowski, 2018).

In STEM Quartet problem-centered learning, the focus of the educational framework put forth by the STEM Quartet is complex, persistent, and expansive problems at their core, with problem-solving as the overarching framework. Providing real-world contextual problems, challenges, and problems provides students with interdisciplinary learning (Tan et al., 2019; Teo et al., 2021).

The perspective within this framework is to address complex, persistent, and expansive problems using hands-on approaches to the four STEM domains that describe the relationships between the STEM fields. A complex problem means that the problem requires more than one scientific discipline to be solved. A persistent problem is a problem that often occurs so that the problem can be the center of organizing knowledge. This concept can be used to explain a problem in different contexts. While the extended problem is broad, it is challenging and requires a long discussion and evaluation to produce a solution (Tan et al., 2019).

The challenge with implementing solution-centered STEM is a variation of the STEM Quartet, where STEM is solution-centric. Students work with specific solutions to a problem by understanding the affordability of specific solutions and the limitations of solutions and trying to understand how solutions can be redesigned for improvement. This STEM Quartet solution approach assumes that existing solutions have limitations, and students will analyze the limitations and think of ways to improve them. Utilizing ideas from information design, teachers can plan integrated STEM learning starting from existing solutions to problems rather than the problem itself (Teo et al., 2021). Figure 1 shows the solution-centric integrated STEM structural framework.

Based on this description, the main objective of this study was to apply the STEM Quartet framework to improve the creative thinking skills of high school students on the topic of renewable energy. In summary, the conceptual framework for this study is shown in Figure 1. Framework for implementing the STEM Quartet for Indonesian high school students. Referring to the law and the Minister of Education and Culture, this research is also based on a theoretical framework containing a description or plan intended to explain all that constitutes the research paper based on the results of the research carried out. The STEM Quartet Framework is described by (Tan et al., 2019) in their journal; solution-centric theory is explained by (Teo et al., 2021); creative thinking skill theory refers to the Torrance indicator (Asriadi & Istiyono, 2020; Khoiri et al., 2019; Tanjung & Nasution, 2023). Therefore, this study aims to improve creative thinking skills for students through the application of the STEM Quartet Framework.

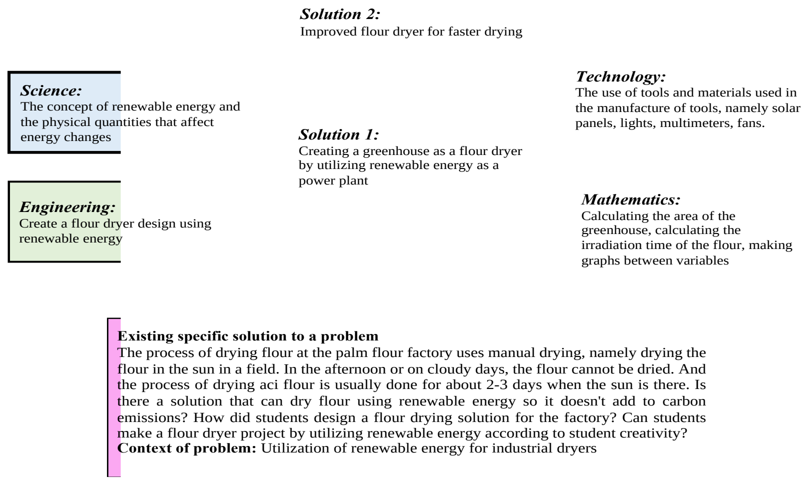

Figure 1 Vertical learning and horizontal connection in STEM quartet

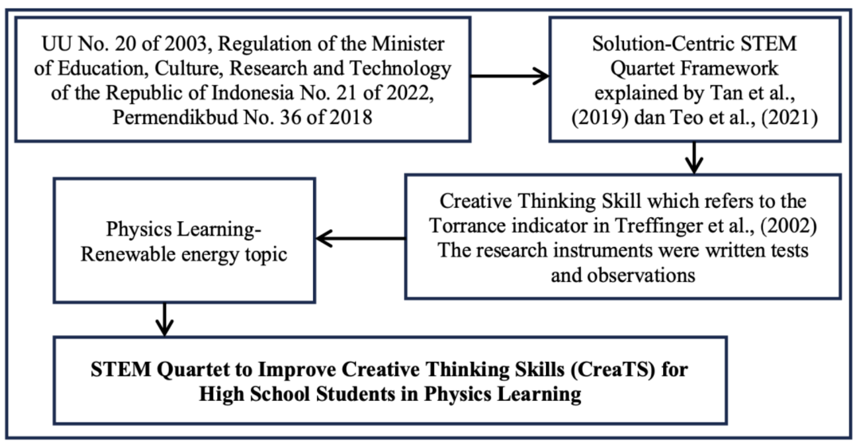

Figure 2 Research framework

METHOD

This study used an experimental design with a pre-experiment method. This research method involves witnessing increased students' creative thinking through results before and after the test and after receiving the STEM Quartet Implementation Treatment. The design used in this study is a group pre-test-post-test design (Creswell & Clark, 2018). The sample was initially tested as a pretest for initial knowledge, then continued with the treatment of applying the STEM Quartet to renewable energy material and tested later using the same tool as the previous test. The test tool used in this study to measure students' creative thinking ability has been verified.

The population of this study included all X-class students of a private high school in Bandung for the 2022/2023 academic year, which consisted of six classes. The sampling technique in this research is a purposive sampling technique, which uses certain considerations according to the desired criteria to determine the number of samples to be studied (Sugiyono, 2018). This study's sample criteria were students who had applied STEM learning. The sample for this study was 16 students aged 15 to 16 years.

This research flow begins by studying the literature related to the STEM Quartet and creative thinking skills. Furthermore, the researcher created a research instrument and then validated the instrument.

The instrument in this study was the CreaTSIT (Creative Thinking Skill Instrument Test) in the form of an essay. This study uses the tools used in the pretest and posttest. The pretest and posttest in the form of questions are based on indicators of creative thinking skills, including four indicators: fluency, flexibility, elaborate, and originality. The tool includes six descriptive questions to identify and measure students' creative thinking skills before and after performing the STEM Quartet.

Study data were analyzed using the N-Gain test to see an increase in creative thinking skills through applying the STEM Quartet by giving a pretest and posttest, as shown by calculating the mean normalized gain <g>.

Table 1 N-gain score category

N-Gain Score	Category
0.70≤ g ≤1.00	High
0.30≤ g < 0.70	Medium
0.00< g <0.030	Low

(Hake, 1998)

RESULT AND DISCUSSION

Based on the results of the pretest before the implementation of the STEM Quartet and the posttest after the implementation of the STEM Quartet, the assessment of creative thinking skills in the form of essay questions with creative thinking skill indicators, namely, there are four indicators, namely, fluency, flexibility, elaboration, originality, and the initial test and final test data were obtained. Summarized in Table 2. Based on the treatment in this research, students are given treatment by providing direct experience related to the material being discussed. Through the STEM Quartet learning stage, students learn independently to develop existing solutions by reviewing the affordability and limitations of existing solutions.

Table 2 Pretest and posttest results data

Score	Min	Max	Mean	Standard Deviation
Pretest	13.33	51.67	28.95	10.14
Posttest	55.00	88.33	77.18	11.47

Table 2 presents the pre- and posttest data obtained in the experimental class. The minimum scores that the students achieved before and after the test were 13.33 and 55.00. while the maximum score before and after the test is 51.67 and 88.33, respectively, showing an increase in the score before and after the test. The maximum score that students achieve on the test before intervention is still relatively low, which shows that when being intervened, applying the STEM Quartet can help and train students to improve their skills. Creative thinking is demonstrated through the maximum score - test score.

The increase in creative thinking skills can be seen from N-Gain. N-Gain is carried out based on the pretest and posttest values of the research samples to see how much the creative thinking skills increase before and after learning, as can be seen in Table 3.

Table 3 N-gain value

Score	Mean	N-Gain	Category
Pretest	28.95	0.67	Medium
Posttest	77.18		

Based on the Table 3, it can be seen that the N-Gain of 0.67 belongs to the medium category, indicating an increase in creative thinking skills in applying the STEM Quartet to 'renewable energy' building materials.
results

The next step is to perform a paired sample t-test. Before performing the paired sample t-test, the normality and uniformity test shall be performed as a condition for the difference test by the paired sample t-test. The data used for the normality test are the mean scores before and after the test.

Table 4 Shapiro-wilk normality test

Type of Data	Sig. Reference (α)	Sig. Count	Category
Pretest	0.05	0.637	Normally distributed
Posttest	0.05	0.016	Not normally distributed

Based on the Shapiro-Wilk normality test with α = 95%, which is summarized in Table 4, it can be seen that Sig obtained the pretest results. Count 0.637 ⩾ 0.05 normally distributed, and posttest results obtained Sig. count 0.016 ⩽ 0.05 not normally distributed. Therefore, the next step is a non-parametric statistical test that uses the Wilcoxon Signed Rank Test to measure the significant difference between the pretest and posttest mean scores of students born before and after implementing the STEM Quartet. The results of the non-parametric Wilcoxon tests are shown in Table 5.

Table 5 Wilcoxon non-parametric test results

		Rank				Test Statistics
		N	Mean Rank	Sum of Ranks	Z	Asymp.Sig. (2-tailed)
Posttest-Pretest	Negative Ranks	0^a	.00	.00	-3.5717^b	0.00
	Positive Ranks	16^b	8.50	136.00		
	Ties	0^c				
	Total	16				

Based on the results of Wilcoxon's signed rank test shown in Table 5, it can be seen that the p-value is 0.00, which means that there is a significant difference between the pretest and pretest scores, after test. A negative rating value of 0 means no data drop between the scores before and after the test. The same result is obtained for a tie value of 0; that is, none of the pretest data is the same as the posttest. Indeed, the data for all 16 students showed increased scores from before to after the test, as indicated by a positive rating value of 16 with a mean rating of 8.50 and a total rating of 136. In addition, the results of Wilcoxon's signed rank test showed a Z value of -3.517 at the 5% significance level, indicating that the calculated Z value is smaller than the Z panel value; H_1 is accepted. This shows that the STEM Quartet.

Creative Thinking Skill N-Gain

The improvement in students' creative thinking skills based on all aspects of creative thinking skills can be seen in Table 6.

Table 6 Improved aspects of creative thinking skills

No.	Indicator of Creative Thinking Skill	Scores			Category
		Pretest	Posttest	N-Gain	
1.	Fluency	37.2	76.30	0.62	Medium
2.	Flexibility	28.8	77.78	0.69	Medium
3.	Elaboration	28.5	75.56	0.66	Medium
4.	Originality	19.6	75.56	0.70	High

The increase in all aspects of the student's creative thinking ability is classified as higher. The fluency aspect has the smallest increase among the other three aspects, 0.6 in the medium category.

Stacking: Changes in students' creative thinking skills

Changes in students' creative thinking skills in renewable energy materials were analyzed by the stacking technique shown through the Wright map, as shown in Figure 4, which visualizes the location of the level of creative thinking skills during the pretest and posttest. The left side of the map places the location of students' creative thinking skills on renewable energy materials. The P code encodes the pretest, while the T code encodes the posttest. For example, P1 shows student number 1, who took the pretest. Code T1 indicates student number 1, who took the posttest. Students' ability to use creative thinking skills on renewable energy materials is distributed on a scale of -7 to +2 logit. The right side of the map shows the location of the question items. Code 1a indicates the first question, part a.

Classically, there is an increase in students' creative thinking skills about renewable energy. Students' average creative thinking ability during the test period was -4.41 on a logit scale. After performing the STEM Quartet learning, the mean increased to 0.51 logit. This shows that STEM implementation positively impacts students' creative thinking skills. This further strengthens the evidence that the STEM Quartet can improve students' creative thinking skills.

From an individual perspective, during the pretest, PLA students have the lowest level of creative thinking skills compared to other students. Meanwhile, LKF students have the highest level of creative thinking skills. After the STEM Quartet learning was carried out, there was an increase in creative thinking skills for all students. The logit value of each student can be seen in Table 7.

Table 7 The logit score of student's creative thinking skills at the pretest and posttest

Name	The Logit Pretest Score	The Logit Posttest Score	Improvement (logit)
LAB	-2.96	1.67	4.63
PAZ	-4.23	1.46	5.69
PAN	-3.69	0.22	3.91
LFW	-5.03	-0.41	4.62
LFF	-5.42	1.46	6.88
PHA	-3.14	1.26	4.4
LKF	-1.96	1.67	3.63
PKB	-3.31	1.46	4.77
PKS	-5.22	1.46	6.68
PLA	-6.26	-1.65	4.61
LMA	-5.82	-0.72	5.1
LMT	-4.45	-1.18	3.27
PNA	-4.84	0.38	5.22
LPN	-4.64	-0.72	3.92
LRH	-4.84	1.67	6.51
PSF	-4.82	0.06	4.88

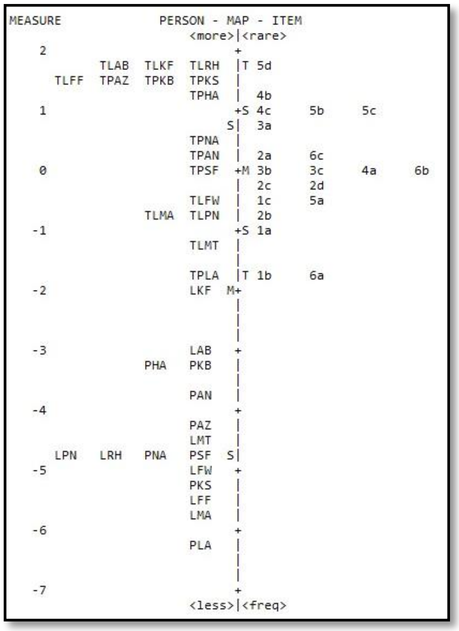

Figure 4 Wright map pretest and posttest students' creative thinking skills

Racking: Item difficulty level changes
Racking analysis shows changes in the difficulty level of the item questions, as seen from the logit value. A high logit value indicates that the problem is difficult to work on, while a low logit value indicates that the problem is easy to work on. An increase in the logit value indicates that the initial questions are considered easy to become difficult. In contrast, a decrease in the logit value indicates a change in questions that were initially difficult to become easy. This decrease in the logit value indicates that the learning carried out has a real effect so that students become more aware of the material after learning (Laliyo et al., 2022; Puspitasari et al., 2022; Sunjaya et al., 2021; Widyasari et al., 2022). Changes in the difficulty level of the items are displayed through the Wright App, as shown in Figure 5, which visualizes the distribution of the difficulty levels of the test items used. The right side of the map shows the distribution of item locations, and the left shows the students. Code P indicates pretest questions, and code T indicates posttest questions. For example, code P1a shows the first question part a, used during the pretest, and T1a shows the first question part a, used during the posttest.

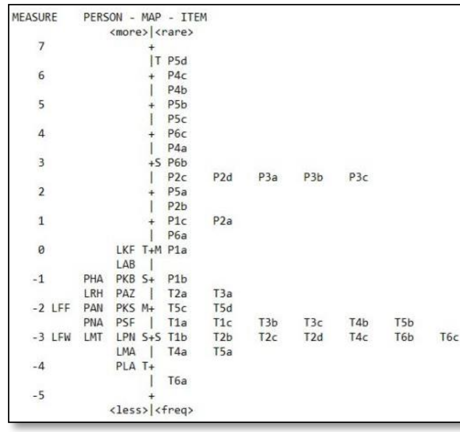

Figure 5 Wright map pretest and posttest of the difficulty level of the questions

Overall, the average difficulty level of the renewable energy questions has decreased. The average difficulty of the questions during the test was -6.26 logit. After completing the learning activities using the STEM Quartet, the average posttest score was +2.76 logit. This is the impact of improving students' creative thinking skills about renewable energy materials.

If seen in more detail from the perspective of the individual questions, question number 1b during the pretest becomes the question with the lowest (easiest) difficulty level for most students, with a logit value of -0.78. The question with the highest difficulty level is question number P5d, with a logit value of 6.29. During the posttest, the logit for question number 1b dropped to -3.16 logit, while for question number 5d, it became -1.75 logit.

The logit value of each question can be seen in Table 8.

Table 8 Logit value of item difficulty at pretest and posttest

Item	Pretest Log Value	Posttest Log in Value	Decrease (logit)
1a	-0.07	-2.74	-2.67
2a	0.83	-1	-1.83
3a	2.71	-1.56	-4.27
4a	3.64	-3.63	-7.27
5a	2.05	-3.39	-5.44
6a	0.31	-4.46	-4.77
1b	-0.78	-3.16	-2.38
2b	1.41	-3.16	-4.57
3b	2.71	-2.74	-5.45
4b	5.48	-2.33	-7.81
5b	5.14	-2.53	-7.67
6b	3.03	-3.16	-6.19
1c	1.11	-2.74	-3.85
2c	2.71	-3.16	-5.87
5c	4.53	-1.95	-6.48
2d	2.38	-2.95	-5.33
3c	2.38	-2.74	-5.12
4c	5.85	-3.16	-9.01
5d	6.29	-1.75	-8.04
6c	3.94	-2.95	-6.89

Table 8 shows that the negative sign on the decreasing logit indicates that the item's difficulty level decreases, the + sign means that the difficulty level of that item increases or becomes more difficult, and 0 indicates the difficulty level of that item; yes, no change. The larger the value difference, the greater the difficulty of the change. (Assyifaa et al., 2021; Sulsilah et al., 2023).

Learning in the class that was carried out by research, there was an increase and change in the level of difficulty of the items according to Table 9, so it can be said that the STEM Quartet affects learning. This happens because the learning stages in the STEM Quartet trigger students to develop fluency, flexibility, originality, and elaboration skills. Table 9 explains the stages of the STEM Quartet.

Table 9 STEM Quartet storyboard based on creative thinking skills

STEM Quartet-Solution Centric	Discussion	Indicator of Creative Thinking Skill
Context of Problem 	Bringing students to an industry and students find problems in that industry.	**(Fluency)** Students can find problems that exist in the industry and find solutions that already exist.
Existing specific solutions to a problem 	Ask questions, provide a variety of ideas, and identify the affordability and limitations of existing solutions to solutions to problems raised on the topic being studied, namely renewable energy.	**(Flexibility)** Students come up with various answers, ideas, and questions and can view an issue from different perspectives.

STEM Quartet-Solution Centric	Discussion	Indicator of Creative Thinking Skill
Formulating solution 	Designed, compiled, and made project plans to solve the selected problem.	**(Originality)** Students think of unique ways for solutions to be created.
Implement Solution 	Designing a renewable solution in response to the affordability and limitations of existing solutions	
Review Solution 	Presenting the advantages and disadvantages of solutions resulting from student discussions with projects that have been made as renewable solutions.	**(Elaboration)** Each group explains and presents the results of their discussion

Based on Table 9, it can be seen that creative thinking skills can be trained by allowing students to look directly at problems and giving students time to formulate solutions to these problems (Heliawati & Pursitasari, 2021; Saregar et al., 2021; Wartono et al., 2018). By providing opportunities and trust for students to be directly involved in making projects or prototypes of renewable solutions from ideas gathered from each student in the group, students can improve their creative thinking skills in research (Habibi et al., 2020; Muchsin & Mariati, 2020) also implement project-based learning, which results in increased creative thinking skills.

Applying the STEM Quartet to learning can train students to think fluently, flexibly, uniquely, and complexly. Because the stages and problem characteristics of the STEM Quartet are complex, persistent, and inclusive (Tan et al., 2019; Teo et al., 2021). Table 6 shows that the number of students increased the least in the aspect of fluency. This shows that students still need to be trained and accustomed to giving ideas smoothly or asking and answering questions to solve a problem. Efforts can be made to familiarize students with continued practice and provide opportunities to improve students' creative thinking skills in all aspects of their creative thinking skills. By choosing the STEM Quartet to train creative thinking skills, students obtain advantages and disadvantages during research. The advantage gained during research is that the teacher has greater control in choosing problems to find solutions and presenting them to students as specific solutions appropriate to the material. However, this study has drawbacks, namely the limited renewable solutions that students can make with the limited time they have during research.

CONCLUSION

Based on the research results, it can be concluded that the STEM Quartet can improve students' creative thinking skills on renewable energy based on an N-Gain score of 0.67 on average. The study's results also showed that all students experienced changes in the increase in creative thinking skills shown in the stacking and racking used in the Rasch model. Learning by applying the STEM Quartet to enhance students' creative thinking skills about renewable energy materials can be an alternative way of learning to improve students' creative thinking skills. In further research, students should be given more time to implement and review the solution. All groups should also be allowed to provide feedback and input for even better solutions. This is because practicing creative thinking skills cannot only be done once but must be accustomed to and repeated so that the results of student improvement are increasing.

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