JPPIPA 10(12) (2024)

Jurnal Penelitian Pendidikan IPA
Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Students' Creative Thinking Skills with STEAM-SDGs Approach to Energy Concept: *Rasch Model* Analysis

Purwanti[1], Muhammad Syaipul Hayat[1]*, Endah Rita Sulistya Dewi[1]

[1]Master of Science Education Postgraduate Study Program, Semarang PGRI University, Indonesia

Received: October 24, 2024
Revised: November 29, 2024
Accepted: December 25, 2024
Published: December 31, 2024

Corresponding Author:
Muhammad Syaipul Hayat
m.syaipulhayat@upgris.ac.id

DOI: 10.29303/jppipa.v10i12.9532

Abstract: 21st century education demands innovation in learning to develop students' creative thinking skills. This study aims to measure the effect of implementing STEAM-SDGs-based science learning on the concept of energy on students' creative thinking skills. The research method used a quasi-experimental method with a one-group pretest-posttest design. The subjects of the study were 32 students of grade VIII of SMP Negeri 1 Jumo, Temanggung Regency. Data collection was carried out using a creative thinking skills test instrument and the research data were analyzed using *the rasch model*. The results showed a significant increase in students' creative thinking skills, with an average pretest score of 35.83 and a posttest score of 82.32. Welch's t-test showed a significant difference between the pretest and posttest (t = -6.31, df = 55, and prob = 0.001, p <0.05). The greatest increase occurred in the fluency, flexibility, and elaboration indicators, while the originality indicator experienced a lower increase. STEAM-SDGs integration has proven effective in improving students' creative thinking skills, with the highest indicator in flexibility (90.24) and the lowest in originality (69.93). This study suggests that combining STEAM with global sustainability issues such as the SDGs can prepare students to face 21st century challenges and increase their awareness of environmental and sustainability issues.

Keywords: Creative Thinking Skills; Energy; Science; SDGs; STEAM

Introduction

In the era of globalization and rapid technological development, creative thinking skills are one of the main competencies that every individual must have (Anindayati & Wahyudi, 2020). Creative thinking skills enable a person to generate new ideas, find innovative solutions to various problems, and adapt to changes in the surrounding environment (Majidah *et al* ., 2024). In the context of education, creative thinking skills are not only important for students' self-development, but are also one of the indicators of the success of education in preparing the younger generation to face the challenges of the 21st century (Rohman *et al*., 2021). Natural Science (IPA) learning has a strategic role in developing creative thinking skills. (Kurnia, 2021; NNL Handayani, 2010). As one of the subjects that teaches basic concepts about nature and the environment, science provides opportunities for students to explore, analyze, and understand natural phenomena through a scientific approach (TW Handayani, 2018 ; Ansya, 2023). However, science learning is often trapped in a traditional approach that tends to prioritize memorizing theoretical concepts without providing space for students to think creatively and explore their knowledge in depth (Qomariyah & Subekti, 2021).

The results of the 2022 Program for International Student Assessment (PISA) survey show that the critical and creative thinking skills of Indonesian students are still lagging behind the international average, a worrying indication of the quality of education in the country (State & OECD, 2023). One of the main factors contributing to this low ability is the learning method which is still dominated by a conventional approach (Sopandi. W, 2017). This approach tends to place less emphasis on the development of problem-solving skills, which are essential in encouraging students to think critically and creatively (Bakti et al., 2023 ; Permanasari & Permana, 2021). In this context, the STEAM (Science,

How to Cite:
Purwanti, P., Hayat, M. S., & Dewi, E. R. S. (2024). Students' Creative Thinking Skills with STEAM-SDGs Approach to Energy Concept: Rasch Model Analysis. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 11152–11161. https://doi.org/10.29303/jppipa.v10i12.9532

Technology, Engineering, Arts, and Mathematics) learning approach emerges as a potential solution that can overcome this problem (Linda, 2023 ; Supriaman, 2023).

The STEAM approach is a learning method that integrates science, technology, engineering, arts, and mathematics (Abed, 2016 ; Stagg & Verde, 2018 ; Stagg, 2019) so that it can create active learning, because the five disciplines must be applied simultaneously in solving problems (Ulfayani et al., 2022; Diana & Turmudi, 2021; Zubaidah, 2019). This approach encourages students to think broadly about real-life problems, which ultimately develops their creative thinking skills (Muntamah et al., 2023). Through this approach, students not only learn scientific concepts, but also develop technical skills, creativity, and critical thinking skills (Rahmawati & Mintohari, 2024; Iffiani et al., 2024). The integration of arts *in* the STEAM approach provides a new dimension in science learning, where students are invited to explore the relationship between science and art. Art is not only used as a tool to convey information, but also as a medium to express creative and innovative ideas (Rahmawati & Mintohari, 2024).

The implementation of STEAM still faces significant challenges. In Indonesia, education with the STEAM approach has been implemented at several levels of education but has not yet occurred massively (Annisa et al., 2019). Most teachers still focus on the traditional curriculum which tends to separate science, mathematics, arts, and technology subjects. Teachers also do not fully understand, design, and implement the STEAM approach in the learning process (Hayat et al., 2023). Many teachers are not yet familiar with the concept of STEAM and how to apply it effectively in the learning process (Agusniatih & R., 2022) and still focus on separating disciplines and emphasizing exam results rather than interdisciplinary and exploratory learning processes (Firdaus & Ritonga, 2024). Research from Probosari et al., (2021) that some teachers have not been able to integrate several fields of science in an integrated manner and how to evaluate them. The learning methods applied still tend to be traditional and not fully in accordance with the times. As a result, students are less trained in critical, creative, and collaborative thinking skills that are much needed in the 21st century. However, the potential of STEAM in equipping students with relevant skills for the 21st century cannot be ignored. This approach not only prepares students to face challenges in an increasingly complex and dynamic world of work, but also encourages them to become global citizens who care about sustainability issues. Through STEAM, students can be invited to connect their knowledge to global issues such as climate change, energy sustainability, and environmental conservation, so that they grow into responsible individuals who are ready to contribute positively to the global community (Damayanti, 2024). The STEAM approach is an approach that can be used to prepare the younger generation to answer the challenges that will be faced in dealing with environmental issues (Nguyen *et al* ., 2020).

In addition to equipping students with soft skills, education must also teach environmental knowledge and create awareness of the importance of sustainability. Education must be able to develop students' awareness of environmental sustainability, form characters that support sustainability, and encourage them to understand and address the impacts of the energy crisis (Vioreza et al., 2023). Thus, students can act as agents of change who contribute to sustainable development and have responsibility for the environment. STEAM offers a holistic approach to achieving this goal. With STEAM, students can learn about global issues such as the energy crisis and climate change, and develop sustainable solutions (Megawati & Arief, 2021 ; Indahwati et al., 2023).

The concept of sustainable development can be realized through education and is an important principle in national education development (Pauw et al., 2015). Machado & Davim, (2022) said the same thing that education is the key to success in achieving the Sustainable Development Goals (SDGs). Education holds the responsibility to shape students in terms of environmental awareness (Sustainability awareness) and change the attitudes of future generations towards the importance of preserving the natural environment (Hamid et al., 2017). SDGs is a global action plan designed by UNDP as an effort to encourage environmentally friendly behavior and balance of life in nature and is an effort to achieve shared prosperity (Khataybeha et al., 2010).

Basic introduction and application of SDGs in school learning needs to be created so that students who act as the next generation have a basic mindset towards social awareness needed to realize sustainable life (Pribadi, 2017). In Indonesia itself, the implementation of SDGs has begun. One of the goals of SDGs is to address environmental problems (Tareze *et al* ., 2022). Of the 17 SDGs goals, two of them are very close to the focus of science education, namely the seventh goal (clean and affordable energy) and the thirteenth goal (addressing climate change). The presence of SDGs provides great hope for restoring the global climate from the negative impacts of parties who do not comply with environmental ethics and do not understand the values of sustainability (Leontinus, 2022).

In science learning that discusses SDGs such as the concept of Renewable Energy, a learning approach is needed that can develop students with knowledge, abilities, and skills. The implementation of the STEAM approach in science learning can also meet one of the

SDGs goals, namely the fourth goal on Quality Education, this goal can be achieved if students have 21st century skills. (Kurniawan, 2023). According to Utami et al., (2024) teachers still have difficulty in preparing learning tools that implement the STEAM approach and still have difficulty connecting learning topics with everyday life using STEAM that supports the SDGs.

The integration of the STEAM approach with SDGs in science learning provides a comprehensive framework for developing students' creative thinking skills (Prihatiningsih, 2024). The STEAM approach based on interdisciplinarity allows students to understand scientific concepts in a broader context, while the SDGs provide a framework that is relevant to global needs. Research conducted by Indahwati *et al*., (2023) shows that the integration of independent learning and the STEAM approach improves students' critical thinking skills and supports the achievement of the 2030 SDGs on renewable energy, and equips students to become agents of change in sustainable development.

Through the synergy between STEAM and SDGs, science learning can be oriented towards the development of creative thinking skills that are not only beneficial for students in academic contexts, but also in real life (Utami *et al*., 2024). In this approach, students are invited to be actively involved in various projects that integrate scientific knowledge with global issues relevant to the SDGs. For example, students can be invited to design creative solutions to environmental problems, such as water pollution or declining air quality, by utilizing the science and technology concepts they have learned (Vioreza & Wilda Hilyati, 2023). In addition, students can also be invited to explore the relationship between art and science in an effort to raise awareness of sustainability issues, such as environmentally friendly product designs or environmental awareness campaigns through art media.

The novelty of this study lies in the integration of the STEAM (*Science, Technology, Engineering, Arts, and Mathematics*) learning approach with *the Sustainable Development Goals* (SDGs) in science learning, especially in the concept of energy. Although the STEAM approach has been applied before, this study focuses on the application of STEAM based on SDGs to improve students' creative thinking skills. By linking energy concept learning to global sustainability goals, such as clean energy and climate change, this study not only develops creative thinking skills but also forms students' awareness of the importance of sustainable awareness. This learning design emphasizes the combination of mastery of scientific concepts and critical and creative thinking skills that are relevant to global challenges. Thus, the results of this study can provide a significant contribution to the development of STEAM-SDGs-oriented science learning strategies to form a generation that is innovative, adaptive, and has awareness of global sustainability issues.

Based on the background description that has been presented, the formulation of the problem in this study is as follows: First, how can the science learning design oriented to STEAM-SDGs in the concept of Energy improve students' creative thinking skills. Second, how is the effectiveness of the science learning design oriented to STEAM-SDGs in the concept of Energy in improving students' creative thinking skills. These two problem formulations will be the main focus of the study to explore and measure the impact of the application of the STEAM-SDGs approach on students' creative thinking skills in the context of science learning, especially in the concept of Energy.

Method

The flow diagram related to the stages carried out in this research is depicted in figure 1.

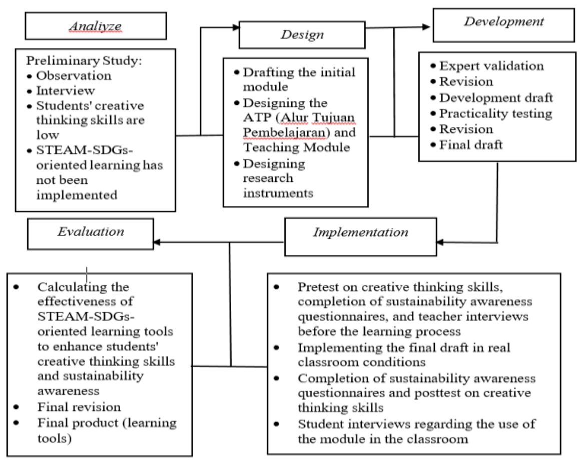

Figure 1 Research Flow Diagram

This research is designed in the form of a research and development design or *Research and Development* (R & D) which refers to the ADDIE model which consists of five stages, namely Analysis, Design, Development, Implementation and Evaluating. This article focuses on the implementation stage using the quasi-experimental method with one-group pretest-posttest design. Data collection was carried out using a creative thinking skills test instrument and the research data were analyzed using *the Rasch model*.

Data collection was carried out by testing twice, namely before the developed product was implemented, students were given treatment in the form of *pre-test questions* and after the developed product was implemented, students were given treatment in the form of *post-test questions* to see the comparison of the results of students' creative thinking skills, before being given treatment and after being given treatment to find out the comparison of creative thinking skills. The subjects in this study were 32 students of class VIII A of SMP Negeri 1 Jumo. The sampling technique used in this study used the *purposive sampling technique* . *Purposive sampling is a sampling determination technique with certain considerations. The reason for using this purposive sampling* technique is because this is a quantitative study that does not require generalization. The data obtained from the pretest and posttest results are calculated as the N-Gain score with Equation 1.

$$\text{Gain (g)} = \frac{\text{post test score} - \text{pre test score}}{\text{maximum score} - \text{pre test score}} \quad (1)$$

The assessment criteria for the creative thinking skills instrument are as in table 1 below:

Table 1. N -gain Effectiveness Criteria (Hake, 1999)

Percentage (%) N-gain	Category
>76	Effective
56 – 76	Quite Effective
40 – 55	Less Effective
< 40	Ineffective

Result and Discussion

The research data represents evidence and findings related to the improvement of creative thinking skills of class VIII A students at SMPN 1 Jumo after participating in the STEAM-SDGs-oriented learning program. The data are presented in the form of average pretest and posttest results, Wright Map Pretest and Posttest Values, t-test and calculation of N-gain values using *Rasch model* analysis to see the effectiveness of implementing the STEAM-SDGs-oriented learning program on students' creative thinking skills. In detail, the research data are presented as follows (Figure 1).

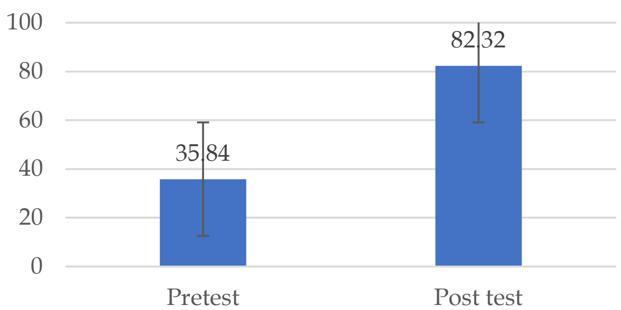

Figure 2. Results of Pretest and Posttest of Students' Creative Thinking Abilities

Based on Figure 1, it shows that there is an increase in *students*' creative thinking skills from a score of 35.84 to 82.32. Then from the data, further analysis was carried out on improving students' creative thinking skills using *the Rasch Model* which can be seen in the following Wright Map results (Figure 2).

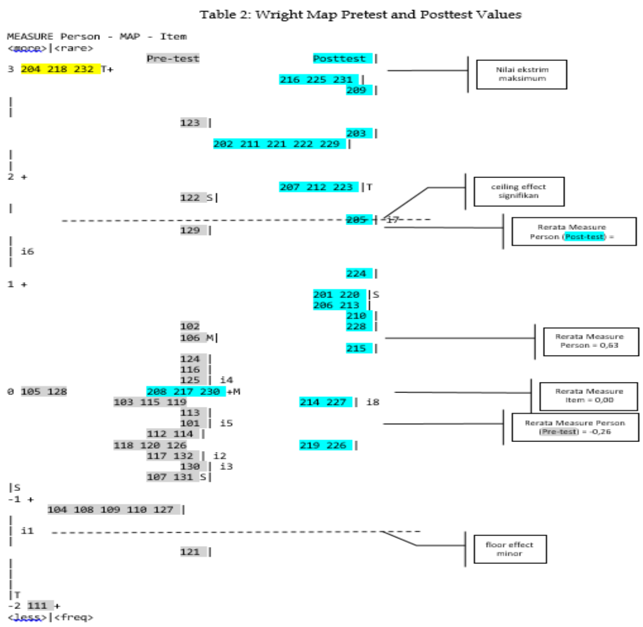

Figure 2. Rasch Model

The data in Figure 3 shows that during the post-test there was a change in the responses given by respondents, person 218 (3.98 logit) is the student who has the highest creative thinking ability, followed by person 232 (3.95 logit) and 204 (3.34 logit). Conversely, person 219 (-0.54 logit) is the student who has the lowest creative thinking ability, followed by person 226 (-0.52 logit). Person 218, 232, 204, 216, 225, 231, 209, 203, 211, 221, 222, 229, 202, 207, 212, and 223 (1.86 logit) have the opportunity to answer all items maximally, because the maximum item measurement is 1.61 logit (i7). In contrast, no person at post-test had a logit value below -1.26 logit (i1).

```
TABLE 28.1 BK ZOU039WS.TXT Sep 28 2024 20:37
INPUT: 64 Person 8 Items REPORTED: 64 Person 8 Item 4 CATS WINSTEPS 5.2.0.0
-------------------------------------------------- ------------------------------
Subtotal specification is: PSUBTOTAL=$S1W1
EXTREME AND NON-EXTREME PERSON SCORES
-------------------------------------------------- -------------------------------------------------- ---------------
| Person MEAN MEAN MEAN SE MODEL TRUE MEAN MODEL |
| COUNT SCORE COUNT MEASURE MEAN P.SD S.SD MEDIAN SEPARATION RELIABILITY RMSE SD OUTFIT CODE |
|------------------------------------------------- -------------------------------------------------- --------------|
| 64 18.2 6.1 .63 .18 1.43 1.44 .13 1.84 .77 .68 1.26 * |
| 32 12.9 5.3 -.26 .16 .91 .93 -.38 1.33 .64 .55 .73 1 |
| 32 23.4 7.0 1.52 .23 1.29 1.31 1.72 1.27 .62 .80 1.01 2 |
-------------------------------------------------- -------------------------------------------------- ---------------
SUBTOTAL RELIABILITY: .95
UMEAN=0 USCALE=1
-----------------------------------------------
| Person MEAN DIFFERENCE Welch-2sided|
| CODE CODE MEASURE SE t df Prob. |
|------------------------------------------------|
| 1 2 -1.79 .28 -6.31 55 .000 |
```

Figure 3. Extreme and Non-Extrem Persson Scores

Based on the wright map and the table above, it can be seen that the average of students' creative thinking ability in the pre-test is -0.26 logit with a standard deviation of 0.93 logit, while the average of students' creative thinking ability in the post-test is 1.52 logit with a standard deviation of 1.31 logit. The average of person measurements in the pre-test is below the average of item measurements (0.00 logit), meaning that in general, students' creative thinking ability in the pre-test is lacking. Conversely, in the post-test the average of person measurements is greater than the average of item measurements (0.00 logit), meaning that in general students have good creative thinking ability in the post-test. This indicates that it is happening in a better direction, namely an increase in students' creative thinking ability. However, in-depth information is known based on the average comparison test between pre-test and post-test data through the Welch t-test. It is known that the value of t = -6.31, df = 55, and prob = 0.000 <α = 0.05, meaning that H0 is rejected and it is concluded that there is a significant difference in the pre-test and post-test scores of students. Furthermore, based on the value of the difference in the average measurement = -1.79 (negative value), meaning that the average pre-test score (-0.26 logit) is less than the average post-test score (1.52 logit). Based on this, it can be concluded that the treatment given causes students' creative thinking abilities to increase significantly. This is reinforced by the visual presentation through the right map, it is clearly seen that there has been a shift in students' creative thinking abilities from the pre-test to the post-test.

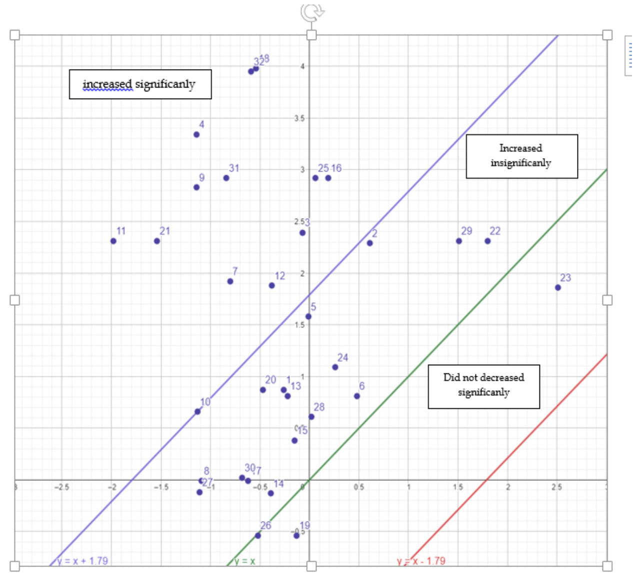

Figure 4. N Gain of Students' Creative Thinking with Rasch Model

In the Gain graph, the changes in responses given by respondents are seen in detail, which generally indicate that there is an increase in students' creative thinking abilities. There are 32 respondents (90.63%) who experienced an increase, with details of 12 respondents increasing significantly and 17 respondents increasing but not significantly. No respondents have stable creative thinking abilities. While the remaining 3 respondents (9.37%) experienced a decrease in creative thinking abilities, but not significantly. Based on the level of each indication of the achievement of creative thinking abilities, it can be seen in Table 3.

Table 4. Categories if Students' Creative Thinking Abilities

Interval Score	Category KBK		Pretest		Posttest
		Number of Studnts	Percentage (%)	Number of Studnts	Percentage (%)
81-100	Very Creative	0	0	20	62.50
61-80	Creative	0	0	12	37.50
41-60	Quite Creative	9	28.12	0	0
21-40	Lack of Creativity	21	65.63	0	0
0-20	Not Creative	2	6.25	0	0
Total		32	100	32	100

Based on Table 4, it can be seen that there is an increase in students' creative thinking skills between the pre-test and post-test which has a significant effect on students' creative thinking. The ability with the Very Creative indicator is 62.50%, Creative 37.5%. The results of the pretest and posttest for each creative thinking indicator when analyzed using SPSS produce data as presented in Table 5.

Table 5. Analysis of Students' Creative Thinking Ability Achievement Indicators

Indicator KBK	Pretest Score	Posttest Score	Score N-gain	Category
Fluency	39.45	85.94	0.76	Quite Effective
Flexibility	53.91	90.24	0.78	Effective
Originality	18.75	69.93	0.62	Quite Effective
Elaboration	31.25	83.20	0.77	Effective

The STEAM approach offers an effective framework for integrating the Sustainable Development Goals (SDGs) into the learning process. Through energy-based projects, students not only gain in-depth knowledge of science and technology concepts, but also actively contribute to efforts to achieve SDGs 7 (Affordable and Clean Energy) and SDGs 13 (Action on Climate Change). With the task of finding innovative solutions and designing simple power plant prototypes, students are encouraged to think critically and creatively in addressing the increasingly pressing energy crisis. These projects are not only relevant to environmental issues, but also encourage the development of clean technologies that have great potential in reducing greenhouse gas emissions and providing equitable energy access for all levels of society.

Based on table 5, the pretest and posttest data show an average pretest of 35.83 and a posttest value of 82.32. For the average pretest value of each indicator, namely the fluency indicator 39.45; flexibility 53.91; originality 18.75 and elaboration 31.25. While the average posttest value of each indicator is the fluency indicator 85.94; flexibility 90.24; originality 69.93 and elaboration 83.20. The gain value is included in the effective category for the flexibility indicator 0.78; and elaboration 0.77. While for the fluency indicator 0.76; originality 0.62 is included in the fairly effective category. This shows that there is an increase in students' creative thinking skills.

The creative thinking indicator in the flexibility aspect has the highest post-test value of 90.24, including the very creative category. Followed by the fluency indicator of 85.94, including the very creative category. The elaboration indicator is ranked third, namely 83.20, including the very creative category, while the originality indicator has the lowest value, namely 69.93, including the creative category. Creative thinking skills with the flexibility indicator develop when students work on LKPD with group discussions where students are asked to find problems and provide solutions to existing problems. Students discuss and put forward various ideas in solving problems in LKPD. The results of this study are in line with the results of research from Budiyono et al., (2020) that the STEAM integrated PBL model can improve flexible thinking skills by 93%.

Fluency and elaboration indicators develop when students are asked to design and create a prototype of a simple power plant, either a water wheel, windmill and utilizing solar panels as an environmentally friendly alternative energy source. The materials, design and method of making a simple power plant prototype are determined by students through discussion and independent learning and seeking information from sources who can explain to students about how to make the prototype. This will stimulate students to create ideas or concepts in designing and creating a simple power plant prototype. In the process of making the tool, students encounter many difficulties and obstacles such as the tool not working with the lights not turning on which are used as indicators of the functioning of the simple power plant prototype. Here students are trained to find problems as the cause of the tool not working and find solutions to repair the tool so that it can function as a simple power plant.

Fluency thinking is also facilitated when students present their work through presentations where students must be able to understand the material, ask questions to other groups and answer questions from other groups. The elaboration indicator is facilitated at the stage of developing and presenting the work where students try to produce good, neat, functional work to produce electrical energy and beautiful (arts). The originality indicator has the lowest value among the other three indicators. Originality thinking skills require students to be able to generate new, unique ideas and think of unusual ways or make unusual combinations. In this indicator, students still have difficulty generating new, unique ideas that are the result of their own thinking. This happens because students are used to answering questions according to the references they get from books or the internet. Students are not used to answering questions with their own ideas.

Figure 4. Students make a water wheel prototype.

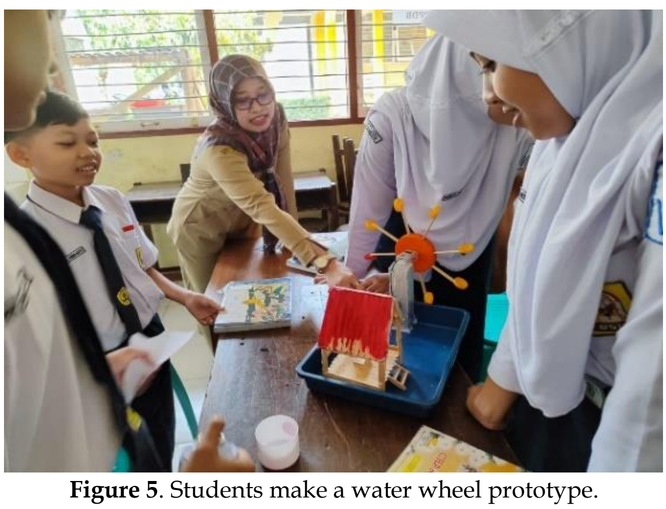

Figure 5. Students make a water wheel prototype.

Figure 6. Students present a simple water wheel prototype.

Figure 7. Students present a simple water wheel prototype

Figure 8. Student product in the form of a simple power generator prototype

Based on the research data, it can be seen that STEAM-SDGs-oriented learning has a significant effect on students' creative thinking skills. This is in line with research conducted by (Hsiao & Su, 2021) on the impact of STEAM-SDGs integration on student learning outcomes showing significant potential benefits. STEAM-SDGs integration not only enriches students' conceptual understanding, but also encourages students to develop a proactive attitude towards global issues and improves students' ability to contribute constructively to problems in the environment and society. Materials or project assignments related to environmental problems will educate students about the importance of protecting the environment and developing creative and innovative solutions to overcome environmental problems. By integrating the STEAM and SDGs approaches in learning such as energy concepts, it will empower students to contribute to realizing the 2030 SDGs (Utami et al., 2024) . The same thing was explained by Jauhariyah et al., (2019) that the introduction of SDGs in physics learning not only provides a deeper understanding of physics concepts but also encourages students to become responsible citizens. By integrating SDGs into science learning, students are encouraged to think creatively and innovatively in finding solutions to environmental problems. They are invited to apply the principles of physics in real life, so that they can actively contribute to efforts to achieve sustainable development goals.

According to Suganda et al., (2021) STEAM can provide positive results on critical thinking skills, creative thinking skills, concept mastery, learning outcomes and problem solving. The same thing was stated by (Hadinugrahaningsih et al., 2017) that the application of the STEAM approach to learning can give rise to creativity and innovation. Research by (Annisa et al., 2019; Witdiya et al., 2023) reported that STEAM learning has an effect on improving the same four aspects, namely fluency, flexibility, originality and elaboration.

The implementation of STEAM learning integrated with SDGs has proven effective in improving students' creative thinking skills. A significant increase can be seen from the comparison of the average pretest and posttest scores which showed a spike from 35.83 to 82.32. Welch's t-test strengthens this finding with results showing a significant difference (t = -6.31, p-value = 0.00 0). In addition, the indicators of flexibility, elaboration, and fluency experienced a greater increase than the originality indicator. This proves that the STEAM-SDGs approach not only improves creative thinking skills but also strengthens the relevance of education to global issues and sustainability, which are very important in equipping students to face the challenges of the 21st century.

Conclusion

Based on the results and discussion of this study, it can be concluded that the application of STEAM-SDGs-oriented learning in the context of science learning, especially on the concept of energy, has a significant impact on improving students' creative thinking skills. The results of the analysis showed a significant increase in students' creative thinking skills, with an average pre-test score increasing from 35.83 to 82.32 in the post-test. Analysis using the Rasch model showed an increase in the average creative thinking ability score from 35.83 in the pre-test to 82.32 in the post-test, with a significant difference (t = -6.31, p-value 0.000). The greatest increase occurred in the flexibility, elaboration and fluency indicators, although the originality indicator still requires further development. Overall, this approach is effective in improving creative thinking skills and emphasizes the importance of integrating education with sustainability issues to prepare students for global challenges.

Acknowledgments
We would like to express our deepest gratitude to the Ministry of Education, Culture, Research, and Technology for the trust that has been given to us through the DRTPM grant. This financial support not only helps us materially, but also motivates the team to carry out research better. We hope that the results of this study can provide a significant contribution to the development of science in the field of education.

Author Contributions
All members of the research team contributed to the writing of this article. "Conceptualization of ideas and literature Purwanti; methodology and instruments, Muhammad Syaipul Hayat; analysis data, Endah Rita Sulistya Dewi".

Funding
This research was funded by DRTPM Kemdikbud Ristek RI

Conflicts of Interest
"The authors declare no conflicts of interest. The funding organizations had no role in the design of the study, the collection, analysis, or interpretation of the data, the writing of the manuscript, or the decision to publish the results. All aspects of the research were conducted independently to ensure objectivity and integrity."

References

Abed, O. H. (2016). Drama-Based Science Teaching and Its Effect on Students ' Understanding of Scientific Concepts and Their Attitudes towards Science Learning. *International Educational Studies. 9*(10), 163–173. https://doi.org/10.5539/ies.v9n10p163

Agusniatih, A., & R., S. M. (2022). Implementasi Pembelajaran STEAM melalui Kegiatan Fun Cooking Sebagai Pembelajaran Abad 21. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *6*(6), 6502–6512. https://doi.org/10.31004/obsesi.v6i6.3418

Anindayati, A., & Wahyudi, W. (2020). Kajian Pendekatan Pembelajaran Stem Dengan Model Pjbl Dalam Mengasah Kemampuan Berpikir Kreatif Matematis Siswa. *EKSAKTA : Jurnal Penelitian dan Pembelajaran MIPA, 5*(2), 217-225. http://dx.doi.org/10.31604/eksakta.v5i2.217-225

Annisa, R., Effendi, M. H., & Damris, D. (2019). Peningkatan Kemampuan Berpikir Kreatif Siswa Dengan Menggunakan Model Project Based Learning Berbasis Steam (Science, Technology, Engineering, Arts Dan Mathematic) Pada Materi Asam Dan Basa Di Sman 11 Kota Jambi. *Journal of The Indonesian Society of Integrated Chemistry*, *10*(2), 14–22. https://doi.org/10.22437/jisic.v10i2.6517

Ansya, Y. A. (2023). Upaya Meningkatkan Minat dan Prestasi Belajar Siswa Kelas IV Sekolah Dasar pada Pembelajaran IPA Menggunakan Strategi PjBL (Project-Based Learning). *Jurnal Ilmu Manajemen Dan Pendidikan (JIMPIAN)*, *3*(1), 43–52. https://doi.org/10.30872/jimpian.v3i1.2225

Bakti, D. B. R. K., Mayasari, T., & Purwandari. (2023). Pengembangan Instrumen Soal Tes Hasil Belajar Berorientasi HOTS Pada Materi Usaha dan Energi. *Seminar Nasional Pendidikan Fisika*, 1–8.

Budiyono, A., Husna, H., & Wildani, A. (2020). Pengaruh Penerapan Model Pbl Terintegrasi Steam Terhadap Kemampuan Berpikir Kreatif Ditinjau Dari Pemahaman Konsep Siswa. *Edusains*, *12*(2), 166–176. https://doi.org/10.15408/es.v12i2.13248

Damayanti, S. (2024). Pengaruh Model Project Based Learning Terhadap Kreativitas. In *Universitas Islam Negeri Raden Intan Lampung*. Universitas Islam Negeri Raden Intan.

Diana, N., & Turmudi, T. (2021). Kesiapan Guru dalam Mengembangkan Modul Berbasis STEM untuk Mendukung Pembelajaran di Abad 21. *Edumatica : Jurnal Pendidikan Matematika*, *11*(02), 1–8. https://doi.org/10.22437/edumatica.v11i02.11720

Firdaus, K., & Ritonga, M. (2024). Peran Teknologi Dalam Mengatasi Krisis Pendidikan di Daerah Terpencil. *Jurnal Kepemimpinan Dan Pengurusan Sekolah*, *9*(1), 43–57. https://doi.org/10.34125/jkps.v9i1.303

Hadinugrahaningsih, T., Rahmawati, Y., & Ridwan, A. (2017). Developing 21st century skills in chemistry classrooms: Opportunities and challenges of STEAM integration. *AIP Conference Proceedings*, *1868*. https://doi.org/10.1063/1.4995107

Handayani, N. N. L. (2010). Pengaruh Model Pembelajaran Inquiry Terbimbing Berbasis Lingkungan Terhadap Keterampilan Berpikir Kreatif dan Penguasaan Konsep IPA Kelas V …. *Jurnal Agama Dan Budaya*, *3*(2), 37–42.

Handayani, T. W. (2018). Improving The Understanding Of The Science Concept Using The Incredible

Inquiry Learning Model In SD Tut Wuri Handayani SD Negeri 3 Pangkalpinang. *Edutainment : Jurnal Ilmu Pendidikan Dan Kependidikan*, *6*(2), 131–153.

Hayat, M. S., Sumarno, S., Yunus, M., & Nada, N. Q. (2023). STEAM-Based "IPAS Project" Learning as a Study of the Implementation of the Independent Curriculum in Vocational Schools. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 12139–12148. https://doi.org/10.29303/jppipa.v9i12.6005

Hsiao, P. W., & Su, C. H. (2021). A study on the impact of steam education for sustainable development courses and its effects on student motivation and learning. *Sustainability (Switzerland)*, *13*(7), 1–24. https://doi.org/10.3390/su13073772

Iffiani, Z., Chaerunnisa, Surudin, Y., Rosdianto, Ngabidin, & Ika Kartika. (2024). Pengembangan Kurikulum Berbasis STEAM (Science, Technology, Engineering, Arts, and Mathematics) untuk Meningkatkan Kreativitas dan Kemampuan Berfikir Kritis. *Reslaj: Religion Education Social Laa Roiba Journal*, *6*(4), 2103–2116. https://doi.org/10.47467/reslaj.v6i4.1217

Indahwati, S. D., Rachmadiarti, F., Hariyono, E., Prahani, B. K., Wibowo, F. C., Bunyamin, M. A. H., & Satriawan, M. (2023). Integration of independent learning and physics innovation in STEAM-based renewable energy education to improve critical thinking skills in the era of Society 5.0 for Sustainable Development Goals (SDGs) 2030. *E3S Web of Conferences*, *450*. https://doi.org/10.1051/e3sconf/202345001010

Jauhariyah, M. N. R., Hariyono, E., Abidin, E. N., & Prahani, B. K. (2019). Fostering Prospective Physics Teachers' Creativity in Analysing Education for Sustainable Development Based Curricula. *Journal of Physics: Conference Series*, *1417*(1). https://doi.org/10.1088/1742-6596/1417/1/012086

Kurnia, A. (2021). Profil Kemampuan Berpikir Kreatif Siswa Menggunakan Soal Tes Pilihan Ganda pada Pembelajaran Ilmu Pengetahuan Alam. *Indonesian Journal of Educational Science (IJES)*, *4*(1), 27–32. https://doi.org/10.31605/ijes.v4i1.1147

Kurniawan, T., Abdurrahman, A., & Rosidin, U. (2024). Implementasi Pembelajaran STEM Berbasis Education for Sustainable Development pada Topik Energi Terbarukan untuk Meningkatkan Kemampuan Berpikir Sistem. *Journal of Teaching and Learning Physics,* *9*(1), 12-22. https://doi.org/10.15575/jotalp.v9i1.28763

Leontinus, G. (2022). Program Dalam Pelaksanaan Tujuan Pembangunan Berkelanjutan (SDGs) Dalam Hal Masalah Perubahan Iklim Di Indonesia. *Jurnal Samudra Geografi*, *5*(1), 43–52. https://doi.org/10.33059/jsg.v5i1.4652

Linda, D. (2023). Analisis Kebutuhan Pengembangan e-LKPD Berbasis STEM-PjBL pada Materi Koloid untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa. *Jurnal Pendidikan Matematika Dan Sains*, *11*(1). https://doi.org/10.21831/jpms.v11i1.59399

Majidah, N., Maulana, A., Nooraida, D., Yanti, R., Mulyani, S., Rusda, A., Yuniar, T., Pratiwi, D. A., & Aslamiah, A. (2024). Implementasi Kurikulum Merdeka Terhadap Keterampilan Berpikir Kreatif Siswa di SDN Alalak Tengah 2. *MARAS: Jurnal Penelitian Multidisiplin*, *2*(3), 1226–1235. https://doi.org/10.60126/maras.v2i3.353

Megawati, L. A., & Arief, B. (2021). Relevansi antara Merdeka Belajar Kampus Merdeka dengan Keterampilan Avad 21 dan SDGs. *Prosiding Seminar Nasional MBKM*, 29–30.

Muntamah, M., Roshayanti, F., & Hayat, M. S. (2023). Potensi Penerapan Pendekatan STEAM (Science, Technology, Engineering, Art, Mathematics) pada Pembelajaran Projek IPAS (Ilmu Pengetahuan Alam dan Sosial) di SMK. *Jurnal Inovasi Pembelajaran Di Sekolah*, *4*(1), 77–83. https://doi.org/10.51874/jips.v4i1.79

Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability (Switzerland)*, *12*(21), 1–16. https://doi.org/10.3390/su12218865

Permanasari, A., & Permana, I. (2021). Profil kemampuan berpikir kreatif dan sikap kreatif siswa kelas vii pada materi pencemaran lingkungan. *Jurnal Pendidikan Kimia. 8(1)*, 31–42.

Pribadi, R. E. (2017). Implementasi Sustainable Development Goals (SDGs) Dalam Meningkatkan Kualitas Pendidikan Di PapuaPribadi, R. E. (2017). Implementasi Sustainable Development Goals (SDGs) Dalam Meningkatkan Kualitas Pendidikan Di Papua. EJournal Ilmu Hubungan Internasional. *EJournal Ilmu Hubungan Internasional*, *5*(3), 917–932.

Prihatiningsih, R. (2024). P*engembangan E-Modul Terintegrasi STEAM (Science , Technology , Engineering , Art , And Mathematics) Pada Materi Kimia Hijau Dalam Pembangunan Berkelanjutan*. Repository. UIN Syarif Hidayatullah

Probosari, R. M., Utami, B., & Widyastuti, F. (2021). Teacher's Candidate Readiness and Beliefs in teaching STEM: Formulating Best Strategy in Scientific Communication. *Journal of Physics: Conference Series*, *1842*(1). https://doi.org/10.1088/1742-6596/1842/1/012011

Qomariyah, D. N., & Subekti, H. (2021). Analisis Kemampuam Berpikir Kreatif:Studi Eksplorasi Siswa Di SMPN 62 Surabaya. *PENSA E-JURNAL: Pendidikan Sains*, *9*(2), 242–246.

Rahmawati, M. D., & Mintohari, M. P. (2024). Implementasi Lkpd Steamboat Berbasis Steam Berbantuan Augmented Reality Untuk Meningkatkan Kemampuan Berpikir Kreatif Di SDN Karangrejo 1. *Ejournal.Unesa.Ac.Id*, 1–15.

Rohman, A., Ishafit, & Husna, H. (2021). Effect of Project Based Learning Model integration with STEAM on Creative Thinking Based on the Understanding of the Physics Concepts of High School Students on Rotation Dynamics. *Jurnal Pendidikan Fisika Tadulako Online*, *9*(1), 15–21.

Sopandi. W. (2017). The quality improvement of learning processes and achievements through the read-answer-discuss-explain-and create learning model implementation. *Proceeding 8th Pedagogy International Seminar 2017: Enhancement of Pedagogy in Cultural Diversity Toward Excellence in Education*, *8*(229), 132–139.

Stagg, B. C. (2019). Meeting Linnaeus : improving comprehension of biological classification and attitudes to plants using drama in primary science education Meeting Linnaeus : improving comprehension of biological classi fi cation and attitudes to plants using drama in prima. *Research in Science & Technological Education*, *00*(00), 1–19. https://doi.org/10.1080/02635143.2019.1605347

Stagg, B. C., & Verde, M. F. (2018). Story of a Seed : educational theatre improves students ' comprehension of plant reproduction and attitudes to plants in primary science education. *Research in Science & Technological Education*, *5143*, 1–21. https://doi.org/10.1080/02635143.2018.1455655

State, T., & OECD. (2023). The State of Learning and Equity in Education Pisa 2022 Results The State of Learning ann. In *Pisa 2022: Vol. I*. https://doi.org/10.31244/9783830998488

Suganda, E., Latifah, S., Irwandani, Sari, P. M., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). STEAM and Environment on students' creative-thinking skills: A meta-analysis study. *Journal of Physics: Conference Series*, *1796*(1). https://doi.org/10.1088/1742-6596/1796/1/012101

Supriaman, R. F. R. (2023). Pembelajaran Pencemaran Lingkungan Menggunakan Model Discovery Learning Berbasis Steam Terhadap Keterampilan Berpikir Kreatif Siswa Kelas X MIPA. *Jurnal Inovasi Pendidikan.* 1(2), 129–142. https://doi.org/10.60132/jip.v1i2.67

Tareze, M., Indri Astuti, & Afandi. (2022). Model Pembelajaran Kolaborasi SDGS Dalam Pendidikan Formal Sebagai Pengenalan Isu Global Untuk Meningkatkan Kesadaran Sosial Peserta Didik. *Visipena*, *13*(1), 42–53. https://doi.org/10.46244/visipena.v13i1.1978

Ulfayani, H., Jeranah, & Asrawati, N. (2022). Efektivitas pendekatan Pembelajaran STEAM Terhadap Hasil Belajar Siswa pada pembelajaran Matematika Kelas VII. *Aritmatika: Jurnal Inovasi Pendidikan Matematika*, *3*(1), 65–70.

Utami, B., Indriyanti, N. Y., Probosari, R. M., Supurwoko, S., Fakhrudin, I. A., Khasanah, A. N., & Hudha, M. N. (2024). Empowering Teachers in Implementing the Project to Strengthen Students' Pancasila Profile Using STEAM-based Learning for Optimizing Sustainable Development Goals (SDGs) in Junior High School. *Masyarakat Berdaya Dan Inovasi*, *5*(2), 1–7. https://doi.org/10.33292/mayadani.v5i2.190

Vioreza, N., Hilyati, W., & Lasminingsih, M. (2023). Education for Sustainable Development: Bagaimana Urgensi Dan Peluang Penerapannya Pada Kurikulum Merdeka? *EUREKA: Journal of Educational Research and Practice*, *1*(1), 34–47.

Vioreza, N., & Wilda Hilyati, M. (2023). Education for Sustainable Development: Bagaimana Urgensi dan Peluang Penerapannya padaKurikulum Merdeka? *PUSAKA: Jurnal of Educational Review.* 1(1) https://doi.org/10.56773/pjer.v1i1.11

Witdiya, T., Supriadi, G., Supriatin, A., & Annovasho, J. (2023). The Effect of STEAM Learning on Improving Each Indicator of Students' Creative Thinking in Physics Learning. *Jurnal Ilmiah Pendidikan Fisika*, *7*(1), 42. https://doi.org/10.20527/jipf.v7i1.7158