Implementation of the 5E Model Integrated STEM-EDP to Enhance High School Students' Creative Problem-Solving Ability

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Abstract *- The improvement of Creative Problem-Solving (CPS) ability in physics learning still needs to be enhanced to prepare students for the challenges of the 21st century. This study aims to determine the effectiveness of implementing the 5E model integrated with STEM-EDP on high school students' CPS ability in the topic of Renewable Energy. This research was conducted at SMA Islam Global Surya using a quasi-experimental method with a pretest-posttest control group design. The sample consisted of class X-1 as the experimental group and class X-2 as the control group. The research instrument used was essay-type questions. The implementation of the 5E model integrated with STEM-EDP was found to be effective in improving students' Creative Problem-Solving ability. This is evident from the average N-Gain score of the experimental class, which was 0.56, higher than the control class with an average N-Gain score of 0.39. Additionally, this finding is supported by the results of the Independent Sample T-Test and Paired Sample T-Test, where the obtained Sig. (2-tailed) value was 0.00 < 0.05. Furthermore, the ANCOVA test results also showed a significance value of 0.00 < 0.05. The effectiveness of implementing the 5E model integrated with STEM-EDP in enhancing high school students' CPS ability in the topic of Renewable Energy falls into the high category, as indicated by the effect size test results, with a partial eta squared (η^2) value of 0.434. This improvement is based on the Constructivism Theory and Behaviorism Theory, which allows students to build new knowledge by connecting it to prior experiences through interactions involving stimulus and response during the learning process.*

Keywords: *5E Model, STEM, Creative Problem Solving; Enggineering Design Process, Renewable Energy*

INTRODUCTION

The development of 21st-century education is marked by the need to prepare students to face global challenges and an increasingly complex and dynamic workforce. Education in this era is not only focused on mastering academic knowledge but also on developing ability relevant to the workplace and daily life (González-Pérez & Ramírez-Montoya, 2022). Currently, these relevant skills refer to 21st-century ability, which consist of Critical Thinking, Creativity, Collaboration, and Communication—commonly known as the 4C ability (Herlinawati et al., 2024).

One of the 4C skills, creativity, is often integrated with problem-solving analysis to help individuals and groups find effective and innovative solutions to the challenges they face. This combination is now recognized as Creative Problem Solving (CPS) ability (Amran et al., 2019; Treffinger & Isaksen, 2005).

Enhancing students' creative problem-solving (CPS) abilities is essential for equipping them to address complex, real-world challenges and adapt to rapid changes across diverse contexts. However, interviews with physics teachers at SMA Islam Global Surya indicate that while CPS training has been implemented, it has not been consistently applied across all topics. As a result, students' CPS abilities remain underdeveloped and require further enhancement.

In current science education, particularly in physics, fostering CPS remains a significant challenge (Rokhmat et al., 2022; Sesriani, 2022). One promising strategy to improve CPS skills is the implementation of the 5E instructional model integrated with the STEM Engineering Design Process (STEM-EDP). The 5E model—comprising Engage, Explore, Explain, Elaborate, and Evaluate—when combined with a STEM approach, supports the development of a deep, practical understanding by encouraging students to engage in interdisciplinary, hands-on activities and collaborative problem-solving (Eroğlu & Bektaş, 2022).

This integration fosters a more holistic and meaningful learning experience, helping students connect scientific concepts with real-world applications. Ultimately, combining the 5E model with STEM-EDP not only enriches the learning process but also better prepares students to face complex and evolving challenges in their academic and future professional lives (Ha et al., 2023).

Research on CPS, which has recently gained new perspectives, has now been linked to specific instructional strategies, one of which is the Engineering Design Process (EDP) strategy. Overall, implementing the STEM approach with the EDP strategy is highly relevant and beneficial in preparing students to become creative and innovative problem solvers in the future while contributing to sustainable development (Abdurrahman et al., 2023). This is further supported by several studies indicating that student engagement at each stage of EDP helps them acquire both content knowledge and essential ability within the learning context (Hafiz & Ayop, 2019; Santi et al., 2021).

CPS also emphasizes the importance of analyzing a problem. Renewable energy, in the context of learning, requires good analysis and understanding as it involves a deep comprehension of natural laws, mathematical modeling, and the ability to interpret empirical data to explain phenomena occurring in the universe. Therefore, it is crucial to introduce renewable energy as an alternative to non-renewable energy through engaging learning. However, in reality, many teachers still face difficulties in delivering lessons about renewable energy in an easy and interesting way (Irawati et al., 2021). Students also find physics difficult due to the numerous formula derivatives and various boring theories related to renewable energy (Jafar, 2021), making it hard for them to understand and analyze information in physics lessons, particularly on the topic of renewable energy.

Therefore, by applying the 5E learning model integrated with STEM-EDP, students' CPS ability are expected to improve. The 5E model, through its instructional sequence, allows students to collect data and independently explore renewable energy-related problems with the support of a STEM approach, which integrates four scientific disciplines. Additionally, the implementation of the EDP strategy will guide students through systematic design stages, such as problem identification, solution development, and prototype creation, fostering creative and innovative thinking.

RESEARCH METHODS

The methods This study employed a quasi-experimental method with a pretest-posttest control group design, involving two class groups: an experimental class and a control class. Both groups participated in pretests and posttests related to Creative

Problem Solving (CPS); however, only the experimental group received a specific treatment, while the control group did not receive any intervention (Creswell & Creswell, 2022; Sahir, 2021).

The sample consisted of 20 students from class X-1 as the experimental group, who were taught using the 5E instructional model integrated with STEM-EDP, and 20 students from class X-2 as the control group, who were taught using the Direct Instruction model with a Scientific Approach. The research instrument used in this study was a CPS ability assessment in the form of a test sheet. This instrument was administered during both the pretest and posttest and consisted of open-ended reasoning-based questions, which were designed based on six CPS skill indicators: fact finding, fact interpreting, idea finding, idea developing, solution generating, and solution evaluating.

The collected data were analyzed using several parametric statistical tests, including N-Gain calculation, Independent Sample T-Test, Paired Sample T-Test, ANCOVA, and Effect Size analysis.

RESULTS AND DISCUSSION

Results

Before the test instrument was used, validity and reliability tests were conducted. The validity test results indicated that all six test items assessing CPS ability in the renewable energy topic were valid, based on the Pearson Correlation value compared to the r-table value of 0.361. Furthermore, the reliability test results showed a Cronbach's Alpha value of 0.644, indicating that the CPS test instrument for the renewable energy topic was considered reliable with a moderate reliability criterion.

Table 1. N-Gain Mean Test Results

Class	Score Achievement	
	Average N-Gain	**Category**
Experimental	0,56	Medium
Control	0,39	Medium

The average N-Gain data presented in Table 1 shows that the experimental class achieved an average N-Gain of 0.56, which falls into the medium category, while the control class obtained an N-Gain of 0.39, also classified as medium. The learning process in the experimental class, which implemented the 5E instructional model integrated with STEM-EDP, resulted in a higher average N-Gain than the control class, which used the Direct Instruction model with a Scientific Approach.

This study employed prerequisite tests, namely the normality test and homogeneity test. Based on the results of these tests, the research data from both the experimental class and control class were found to be normally distributed and had equal variance (homogeneous), as indicated by a Sig. value greater than 0.05 ($\alpha > 0.05$).

Table 2. Independent Sample T-Test Results

	Sig. (2-*tailed*)
Experimental	0,000
Control	0,000

The Independent Sample T-Test results presented in Table 2 indicate that the Sig. (2-tailed) value is 0.00 < 0.05. This finding suggests that there is a significant difference in the improvement of CPS ability between students taught using the 5E instructional model integrated with STEM-EDP and those taught using the Direct Instruction model with a Scientific Approach.

Table 3. Paired Sampe T-Test Results

	Sig. (2-*tailed*)
*Pretest*_Experimental *Posttest*_ Experimental	0,000
*Pretest*_Control *Posttest*_Control	0,000

The Paired Sample T-Test results presented in Table 3 indicate that the Sig. (2-

tailed) value is 0.00 < 0.05. This result suggests that there is a significant difference in the improvement of Creative Problem-Solving (CPS) ability before and after being taught using the 5E instructional model integrated with STEM-EDP in the experimental class. Additionally, a significant difference was also observed in the improvement of CPS ability before and after being taught using the Direct Instruction model with a Scientific Approach in the control class.

Table 4. ANCOVA Test Results

Source	Sig.	*Partial Eta Squared*
Correct Model	0,000	0,434
Intercept	0,000	0,730

The ANCOVA test results presented in Table 6 show that the Sig. value for the Correct Model source is 0.00 < 0.05. This indicates that the 5E instructional model integrated with STEM-EDP is effective in enhancing students' Creative Problem-Solving (CPS) ability in the renewable energy topic. The impact of implementing the 5E instructional model integrated with STEM-EDP on improving students' CPS ability in the renewable energy topic falls into the large category, as indicated by the Partial Eta Squared value of 0.434 (0.14 ≤ 0.434).

Discussion

Students' CPS ability in this study was measured using a test instrument consisting of six open-ended questions, administered before the learning process (pretest) and after the learning process (posttest). Figure 1 below illustrates the increase in CPS ability for each indicator, based on the pretest and posttest score results.

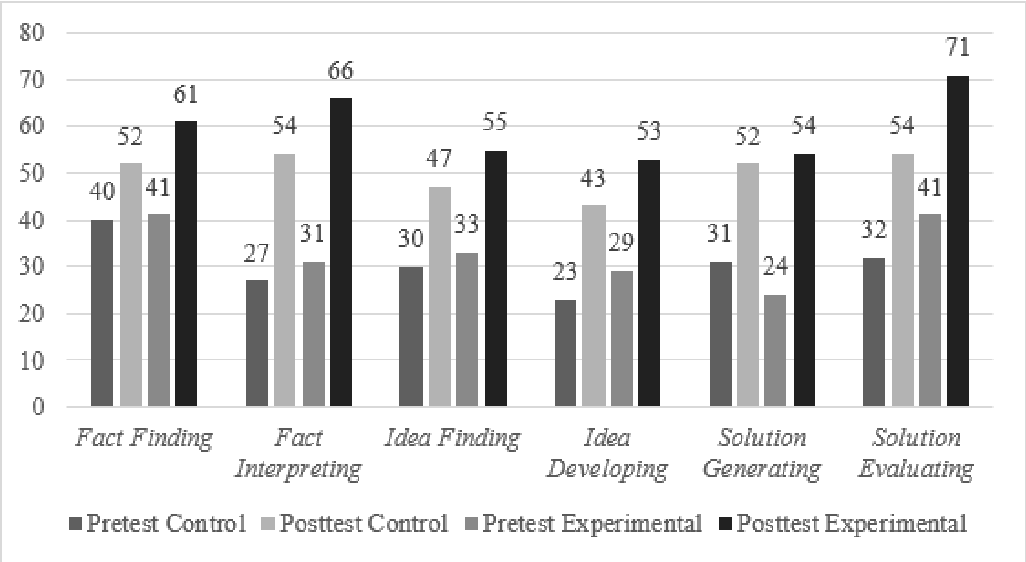

Figure 1. Diagram of Students' CPS Ability Improvement

The diagram of students' CPS ability improvement presented in Figure 4 shows that the experimental class, which received treatment through the implementation of the 5E instructional model integrated with STEM-EDP, experienced a higher improvement compared to the control class, which was taught using the Direct Instruction model with a Scientific Approach.

Specifically, the pretest results for the solution-generating indicator in the control class were higher than those in the experimental class. However, after the posttest, the experimental class showed a greater improvement compared to the control class. Additionally, a higher increase in students' CPS ability was also observed in the solution-evaluating indicator.

This can be attributed to the learning process, particularly during the elaboration phase, which emphasizes the solution-generating indicator, and the evaluation phase, which focuses on the solution-evaluating indicator, where STEM aspects were fully integrated. The integration of STEM approaches in learning encourages students to actively participate, develop critical thinking skills, analyze problems, and find innovative solutions.

The STEM learning approach, which combines various disciplines, including physics, allows students to see the interconnections between concepts comprehensively, thereby deepening their understanding of physics concepts (Ardianti et al., 2020; Davidson et al., 2019; Kurup et al., 2019).

The 5E learning cycle consists of five stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Bybee, 2014; Putra et al., 2018). During the engagement stage, students identify factual problems arising from the increased consumption of fossil fuels by formulating problem statements that explain the cause-and-effect relationship of rising fossil fuel consumption globally and in Indonesia. This activity stimulates the CPS ability in the fact-finding indicator, allowing students to discover relevant and accurate information about the given problem. The fact-finding phase is a key step in encouraging individuals to examine issues in depth and triggering mindset shifts that enable them to adopt more sustainable strategies and practices (P. Chen & Chang, 2024).

Subsequently, in the exploration stage, students explore various sources related to the potential of renewable energy in Lampung Province. They also investigate the efficiency of solar panel usage. This activity stimulates the fact-interpreting indicator of CPS ability, as students analyze and evaluate information obtained from data exploration on total electricity production and consumption in Lampung Province. Additionally, they interpret factual data from calculations to determine the number of solar panels required to achieve a specific electricity output.

In the explanation stage, which is integrated with STEM-EDP, students work in groups to explain and propose several alternative problem-solving ideas for optimizing solar panel usage, one of the renewable energy potentials in Lampung Province. They also analyze the strengths and weaknesses of each idea before selecting or combining them into a problem-solving design. This activity stimulates the idea-finding and idea-developing indicators of CPS ability. According to Amran et al. (2019), CPS ability involves the creative thinking process, which is essential for generating new ideas and innovative solutions to problems. CPS encourages students to learn independently or collaboratively while fostering creativity in identifying various solutions (Wang, 2019). This stage is a crucial aspect of creativity, which plays a significant role in solving real-world complex problems and serves as a key driver that helps societies advance through innovation and adaptation to new challenges (Sawyer & Henriksen, 2024).

Subsequently, in the elaboration stage, students apply their concepts by designing and constructing a simple solar power prototype (PLTS) using a solar cell to rotate a fan blade. This conceptual application in the elaboration stage indicates that students understand the taught concepts and can apply their knowledge to create a working prototype. According to Purwanto (2020), an individual’s ability to solve problems highly depends on their understanding of fundamental concepts and principles. This understanding provides a strong foundation for analyzing, identifying solutions, and making effective decisions. This activity stimulates the solution-generating indicator of CPS ability, as students plan appropriate steps in implementing the selected solution. Each step in the CPS problem-solving process emphasizes the importance of identifying multiple alternative ideas to ensure that solutions are not only innovative but also practical and applicable (Mahrani et al., 2023).

Figure 2. Prototype Testing

The final stage of the 5E learning model is evaluation, where students test and review the solar power prototype with a solar cell they have constructed to rotate a fan blade. Figure 2 shows students' activities during the evaluation stage. Through the evaluation stage, students develop analytical skills by considering different problem-solving approaches and evaluating the effectiveness of each solution (Musfiroh et al., 2024). The evaluation activities integrated with STEM-EDP stimulate students' abilities to assess the success of the implemented solution and develop strategies for improvement if needed. This corresponds to the solution-evaluating indicator of CPS ability.

The summary of the test item specifications for each indicator is presented in Table 5.

Table 5. Test Item Indicators

CPS Ability Indicators	Test Item Indicators
Fact Finding	Formulating a problem statement based on the presented data, supported by several relevant contextual factors such as economic factors, population growth, dependence on fossil energy, and the potential of renewable energy. The statement should present a cause-and-effect relationship related to the urgency of energy needs in Indonesia.
Fact Interpreting	Interpreting the facts effectively by providing a clear, detailed, and structured analysis of the solution, including a conclusion based on the calculations about light intensity.
Idea Finding	Proposing three creative ideas to optimize the use of solar panels that are innovative, realistic, and aligned with energy challenges in Lampung, along with a brief description of each idea.
Idea Developing	Evaluating and developing creative ideas into more specific solutions by listing three advantages and disadvantages for each idea, as well as selecting one idea or a combination of ideas, referring to the renewable energy potential in Lampung.
Solution Generating	Creating a simple design of a solar power system with solar cells to rotate a small propeller, featuring clear labels of the materials used.
Solution Evaluating	Provide output power calculations for the three solution options to increase the output power of solar panels correctly and completely, and compare their effectiveness clearly by providing reasons for the selection of options based on the results of logical and in-depth analysis.

The instrument has been modified to align with the 5E model of learning integrated with STEM-EDP. These adjustments are implemented to ensure that the instrument fosters learners' active engagement in each stage of the learning process, as well as encourages them to identify problems, design solutions, and systematically evaluate results. Therefore, the instrument is expected to enhancing students' CPS abilities.

The discussion above demonstrates that students taught using the 5E model are empowered to connect new information with prior knowledge. This learning model is oriented toward investigation and discovery, ultimately leading to problem-solving. As a result, the learning process becomes more meaningful by prioritizing real-life experiences commonly encountered in students' daily lives while avoiding conventional memorization-based learning methods (Rahmawati, 2024). The integration of STEM-EDP in physics education can provide students with real-world experiences and encourage their engagement by incorporating technology into a challenging STEM learning environment (Di et al., 2021; Struyf et al., 2019). This approach also offers students the opportunity to understand authentic contexts and develop technical skills relevant to STEM disciplines (Abdurrahman, 2023). Other studies also highlight that the 5E learning model provides an effective platform to enhance motivation, attitudes, academic achievement, creativity, and critical thinking skills among students (Ranjan & Padmanabhan, 2018).

CONCLUSION

The results of this study indicate that the 5E learning model integrated with STEM-EDP is effective in enhancing high school students' CPS abilities on the topic of renewable energy. This is evident from the average N-Gain score of the experimental class, which was taught using the 5E learning model integrated with STEM-EDP, at 0.565, compared to the control class, which was taught using the Direct Instruction model with a Scientific approach, at 0.395.

The hypothesis test results, specifically the Independent Sample T-Test, yielded a Sig. (2-tailed) value of $0.00 < 0.05$, indicating a significant difference in CPS improvement between students taught using the 5E model integrated with STEM-EDP and those taught using the Direct Instruction model with a Scientific approach. Additionally, the Paired Sample T-Test results for the experimental class showed a Sig. (2-tailed) value of $0.000 < 0.05$, confirming a significant improvement in students' CPS abilities before and after being taught with the 5E model integrated with STEM-EDP.

This finding is further reinforced by the ANCOVA test results, which produced a Sig. value of $0.00 < 0.05$, signifying that the 5E model integrated with STEM-EDP is effective in enhancing students' CPS abilities in renewable energy topics, with a large effect size as indicated by the partial eta squared (η^2) value of 0.434.

A recommendation for future research is to develop instructional modules based on the 5E model integrated with STEM-EDP, specifically designed for other renewable energy topics such as wind, hydro, or biomass energy. This approach would enable a more comprehensive learning experience and further support the enhancement of students' competencies.

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