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# Developing Students' Creative and Entrepreneurial Skills via Project-based STEM Physics

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**Abstract**

Physics is a complex subject and requires a high level of understanding. Based on interviews at SMAN 4 Langsa, there has never been a test of creative thinking skills, there has been no learning that develops these skills, and students have a low entrepreneurial spirit. This study aims to improve physics learning through the PjBL-STEM (Project-Based Learning-Science, Technology, Engineering, and Mathematics) model, in improving students' creative thinking skills and entrepreneurial spirit. The research design used in this study was a one-group pretest-posttest design involving 89 grade X students. Data collection was conducted through interviews, questionnaires, and tests developed based on indicators of creative thinking skills. The data were analysed using the percentage formula, N-gain, Normality, and Paired Sample t-test. The instruments used were the Creative Thinking Skills Test and the Entrepreneurship Questionnaire. The results showed that the average N-gain of 0.71 was categorised as high. Based on the N-gain results, it can be concluded that there is an increase between before and after treatment. The results of the entrepreneurship questionnaire showed 45% before treatment and 82% after treatment. From the results of this study, it can be concluded that the PjBL-STEM model can optimise physics learning by improving students' creative thinking skills and entrepreneurial spirit.



## 1. Introduction

Creative thinking skills are one of the educational problems in Indonesia. According to the Global Index of creativity results, Indonesia is ranked at the bottom of the creative and innovative index [1]. This is supported by Kadir & Rahmawati's research [2], which shows that students' creative thinking skills remain low. Creative thinking needs to be developed and taught to students to solve problems, be independent, and create reliable, skilled human resources [3]. Students' creative thinking can be seen from several aspects, namely fluency, elaboration, flexibility, and originality [4, 5]. Creative thinking enables individuals to generate innovative solutions, think outside the box, and adapt to change [6].

The latest definitions of creative thinking are growing increasingly complex, namely a process of cognitive in students responding to an object, problem, condition, which aims to solve a problem [7], a person's ability to create or produce something new, both in the form of ideas and products [8], the competence to engage productively in generating, evaluating and improving ideas, which can result in original, effective, visionary and imaginative solutions with positive impact [9]. Developing students' creative thinking skills will foster creativity and enable them to solve problems in many ways through different perceptions and concepts [10].

Several factors, both internal and external, can contribute to low levels of creative thinking skills. Internal factors include a lack of motivation to learn, fear of failure, and low self-confidence. At the same time, external factors include less varied learning methods, a less conducive learning environment, and a lack of teacher stimulation [11]. Based on preliminary observations at SMAN 4 Langsa, conducted interviews with physics teachers, and information obtained, students still find it difficult to remember the physics material, as evidenced by students' average daily test scores remaining below the passing standard. Many students lack the courage to give opinions and are less innovative. The teacher also added that many students still cannot solve problems from different perspectives because they lack self-confidence.

The development of entrepreneurial spirit is also an important aspect of the learning curriculum in Indonesia [12]. Schools also have a responsibility to foster entrepreneurial spirit through entrepreneurship education [13]. Entrepreneurial skills are needed to compete and survive in this era. Entrepreneurial attitudes that entrepreneurs must master include self-directedness, self-confidence, action orientation, energy, and tolerance [14]. In line with the independent curriculum, students are required to think creatively and demonstrate an entrepreneurial spirit. These two skills are integrated to create learners who are not only able to think critically and creatively but also ready to contribute productively in society. To overcome this problem, an innovative learning approach that is relevant to the needs of the 21st century is needed. One learning model that is considered effective is Project-Based Learning (PjBL) integrated with the STEM (Science, Technology, Engineering, and Mathematics) approach.

PjBL is one of the learning approaches that enable students to construct knowledge in groups using scientific methods [15]. PjBL is a model for implementing projects in which students investigate real-world problems in groups [16]. Through PjBL, students can engage in the learning process in groups, allowing teachers to manage classroom learning by engaging students in project work and for students to create creative projects by exploring their knowledge [17, 18]. Currently, Science, Technology, Engineering, and Mathematics (STEM) must be integrated into science learning. The STEM learning approach can foster meaningful learning for students by integrating mathematical knowledge, concepts, and skills [19]. An important aspect of STEM learning is the Engineering Design Process (EDP). EDP is one approach to integrating STEM into learning [20]. Through this aspect of EDP, students can appreciate a wide range of ideas, solve complex problems with multiple solutions, and use a variety of representative tools to produce the desired end product.

The PjBL-STEM relationship can be used as an innovative learning approach, in which PjBL requires students to create a project, while STEM is a component with interrelationships across disciplines. PJBL-STEM can create a holistic, dynamic learning environment that prepares students for academic, workplace, and daily-life challenges. This approach ensures students master the theoretical knowledge and practical skills needed to innovate and adapt in the 21st century [21]. Using the PjBL STEM model will prepare students for challenges in the business and industrial worlds. Based on previous research, PjBL-STEM has a significant impact on science learning, namely, it can optimise learning activities and students' creative thinking skills [22], improve the level of student creativity and entrepreneurial spirit [23], improve problem-solving skills [24, 25], and improve mastery of student concepts [16].

Students' creative thinking and entrepreneurial spirit should be integrated into alternative energy materials, as these skills encourage them to develop innovative and sustainable solutions to global challenges, such as the energy crisis and climate change. Thus, students not only understand the concept of renewable energy theoretically, but are also ready to contribute to creating a sustainable future. Therefore, this research aims to develop PjBL tools using a STEM approach to enhance creative thinking skills and entrepreneurial spirit in physics education related to alternative energy materials. The formulation of the research questions is as follows: How does learning using the PjBl-STEM model improve students' creative thinking skills, and how does the treatment affect students' entrepreneurial spirit?

## 2. Materials and Methods

The research methods used are qualitative and quantitative. The research design is a pre-experimental, one-group, pre-test and post-test design. Design pre-experimental is the only design in which a single group or class is given a pre-test and post-test without a comparison group [26]. This research was performed in the even semester of the 2024/2025 academic year at SMAN 4 Langsa, located in Langsa Barat, Aceh. The study population comprised all students in grade X at SMA 4 Langsa. The research subjects were selected using a

**Table 1.** Student creative thinking skills data.

| No | Creative Thinking Indicators | Pretest (%) | Posttest (%) |
|---|---|---|---|
| 1 | Elaboration | 51.3 | 89 |
| 2 | Flexibility | 26 | 85 |
| 3 | Fluency | 28.3 | 80 |
| 4 | Originality | 35.6 | 82 |

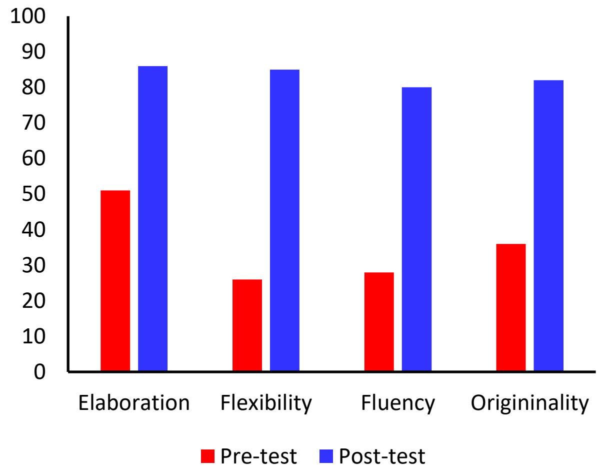


**Figure 1.** Students' creative thinking data based on pre-test and post-test.

**Table 2.** Data N-Gain score of creative thinking skills.

| Class | Mean | N-Gain |
|---|---|---|
| Pre-test | 40.5 | 0.71 |
| Post- test | 86.4 | |

**Table 3.** Data normality results.

| Class | Statistic | Df | Sig. |
|---|---|---|---|
| Pre | .081 | 89 | .051 |
| Post | .079 | 89 | .065 |

purposive sampling technique. There were 89 students from classes X.E-1, X.E-2, and X.E-3.

The research instrument consists of a creative thinking skills test in the form of descriptions, totalling five questions, and questionnaires to measure entrepreneurial spirit. The instrument's items have been tested by experts and empirically. Data were collected in two stages: pre-test and post-test. The pre-test was given to students studying alternative energy in the initial stage. After that, the students received the learning treatment through the PjBL-STEM model, and in the final stage, the post-test was administered.

Data in this study were analysed in two stages. The first stage was the quantitative analysis of students' creative thinking skills after treatment. Calculation of students' creative thinking skills using normality gain [27]. The Shapiro-Wilk normality test [28] and the Paired-samples t-test to assess the effectiveness of the treatment [29].

The second stage, qualitative analysis of the entrepreneurial spirit questionnaires, uses percentage formulas. In this study, data analysis was conducted using SPSS software.

## 3. Results and Discussion

### *3.1. Student Creative Thinking Skills Data*

Data on students' creative thinking skills, based on pre-test and post-test results, are presented in Table 1. Grouping of pre-test and post-test scores is based on indicators of creative thinking skills. 1) Fluency (Thinking fluently), 2) Elaboration (Building concept linkages), 3) Flexibility (Seeing from different points of view), 4) Originality (Use of relatively new ideas). The results are shown in Table 1.

The improvement in students' creative thinking skills after learning using the PjBL-STEM model, as indicated by pre-test and post-test scores, is shown in Figure 1.

The increase in students' creative thinking skills is evident in the average N-gain scores in the research class [30]. According to Table 2, the average N-Gain of 0.71 falls within the high category. This shows an increase between the before and after treatment periods, namely when using the PjBL-STEM model. The magnitude of the N-Gain value obtained was due to the class learning by applying the PjBL-STEM model as an alternative learning method and by using the STEM approach's steps in the learning process.

The data in this study were tested for normality using the Kolmogorov-Smirnov test. To determine whether the data are normal, if sig > 0.05, the data are normal; if sig < 0.05, the data are abnormal. The calculation results are as follows in Table 3.

Based on the output, the two variables had p-values of 0.081 and 0.079, with significance values of 0.051 and 0.065, respectively. In this test, the decision is to reject H0 if the p-value is less than the significance level (0.05). Since the p-value is greater than the significance level, the decision fails to reject H0, and the two variables are concluded to be normally distributed.

After the normality test is carried out, a hypothesis test can be performed using the t-test to determine whether there are significant differences between classes taught without treatment and classes that used the PjBL-STEM to improve students' critical thinking skills. The hypothesis test used in this research is a parametric statistical test: the paired-samples T-test. This test is used to decide whether the hypothesis is accepted or rejected. The hypothesis in this research is shown in Table 4.

**Table 4.** Hypothesis test results.

| Class | Mean | Std. deviation | df | Sig. (2-tailed) |
|---|---|---|---|---|
| Pretest - Posttest | 28.62500 | -14.14 | 89 | .000 |

**Table 5.** Students' entrepreneurial spirit data.

| | Percentage (%) | |
|---|---|---|
| **Indicators** | **Before Treatment** | **After Treatment** |
| Need of Achievement | 42 | 86 |
| Entrepreneurial Alertness | 45 | 78 |
| Risk Tolerance | 53 | 80 |
| Self-Confidence | 41 | 85 |
| Average | 45 | 82 |

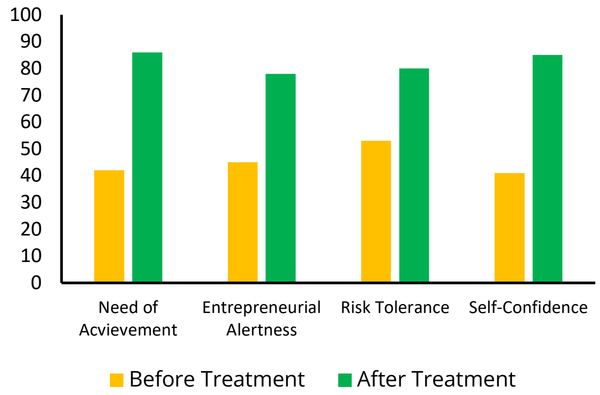


**Figure 2**. Students' entrepreneurial spirit data.

In this test, the decision is to reject H0 if the p-value is less than the significance level (0.05). From the table, the sig. is < .005. It can be concluded that students' creative thinking skills differ before and after being taught using PjBL-STEM. These results are supported by research results from Saefullah et al. [31], Widyasmah & Herlina [32], Hasibuan et al. [33], and Djafar et al. [34]. They said that learning through the PjBL model integrated with STEM can improve students' critical thinking skills.

*3.2. Students' Entrepreneurial Spirit Data*

This research also analyzed students' entrepreneurial spirit in the context of alternative energy materials, with the measured indicators including need for achievement, entrepreneurial alertness, risk tolerance, and self-confidence. The results of the data analysis on students' entrepreneurial spirit before and after learning using the PjBL-STEM model are presented in Table 5, while the differences in students' entrepreneurial spirit following the implementation of the PjBL-STEM model are illustrated in Figure 2.

In the need for achievement indicator, using the PjBL-STEM model, students are enthusiastic about making products. Various ideas and student creativity emerge as the product is completed. The need for achievement indicator measures students based on their success in creating products and finding the latest innovations. This improvement is supported by research results from Ilma et al. [30] and Baran et al. [35].

In the entrepreneurial alert indicator, students look for ideas to design more flexible products, use low-cost tools and materials, and identify market opportunities to sell them. The entrepreneurial alert indicator measures the extent to which students seek business ideas and ways to develop them. According to research by Dhani & Yulianti [36] and Rusman et al. [37], the PjBL-STEM can enhance students' entrepreneurial skills.

In the self-confidence indicator, students have confidence when making products and selling the results. Learning through PjBL-STEM enables students to create products that meet expectations and desires. The products are well received by consumers, enabling them to achieve their planned entrepreneurial targets. The research results from Meita [38] indicated that the application of PjBL-STEM enables students to produce products that meet school and industry standards and are ready for the industrial world.

In the risk-taking indicator, students dare to create new ideas for their products, consider the risks they may face, and set clear targets to minimise potential risks. The characteristic of STEM is that it emphasises the process of designing 'engineering' as a systematic approach to developing solutions to well-defined problems, namely determining the best solution or process from the ideas that arise [39].

## 4. Conclusions

The implementation of the PjBL-STEM learning model in alternative energy materials proved to be effective in enhancing both students' creative thinking skills and entrepreneurial spirit. The significant increase in students' creative thinking, as indicated by the high N-Gain score of 0.71 and the paired-sample t-test results (sig. < 0.05), demonstrates that students experienced meaningful cognitive improvement after the treatment.

All indicators of creative thinking, fluency, elaboration, flexibility, and originality showed substantial growth. In addition, students' entrepreneurial spirit also improved markedly across all indicators, including need for achievement, entrepreneurial alertness, risk tolerance, and self-confidence, with the average percentage rising from 45% to 82%. These findings confirm that the PjBL-STEM model not only strengthens students' higher-order thinking skills but also fosters entrepreneurial characteristics, preparing students to be more innovative, confident, and capable of facing real-world challenges in the context of sustainable energy.

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