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The Influence of Project Based Learning Model on Creative Thinking Skills and Physics Learning Outcomes

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Abstract: This study examines the impact of the Project-Based Learning (PjBL) model on high school students' creative thinking skills and physics learning outcomes. Using a quasi-experimental design with a Nonequivalent Control Group, data were collected through pre-tests and post-tests from 71 students divided into experimental and control classes at SMAN 1 Gerung. The findings reveal that the PjBL model significantly enhances students' creative thinking skills, with the experimental class showing a higher improvement (from 42.58 to 76.29) compared to the control class (from 37.41 to 67.77). Additionally, the PjBL model effectively improves cognitive, affective, and psychomotor outcomes, as evidenced by higher post-test scores and improved engagement, collaboration, and responsibility among students in the experimental class. These results suggest that the PjBL model is an innovative and effective approach to fostering 21st-century skills such as creativity, problem-solving, and critical thinking while addressing the limitations of traditional, teacher-centered methods. This research contributes to the development of interactive and student-centered teaching strategies, particularly in physics education, and provides valuable insights for enhancing academic and life skills in students.

Keywords: Creative thinking skills; Learning outcomes; Physics education; Project-Based Learning (PjBL); Quasi-experimental; Student engagement; Student performance; Traditional learning models.

Introduction

Learning in the 21st century is marked by the increasing integration of information and communication technology across various domains, including education (Baroya, 2018). In this era, the primary objective of education is to foster not only intellectual and moral development but also essential skills such as creativity, problem-solving, and knowledge mastery (Syamina et al., 2021; Sharma et al., 2020). This aligns with the fundamental shifts of the 21st century that demand high-quality human resources capable of producing exceptional performance (Hagi et al., 2021). Consequently, students must acquire proficiency in science and technology, assess their impacts and benefits, and cultivate a lifestyle that is creative, innovative, intelligent, and globally competent (Hagi et al., 2021). One such crucial skill is creative thinking, which involves generating new, original, and unique solutions to problems (Hagi et al., 2021). According to MZ et al. (2021), creative thinking enhances problem-solving and helps develop advanced cognitive skills. Moreover, it improves learning processes and outcomes, enabling students to tackle real-world challenges (Guo et al., 2020).

Despite the recognized importance of creative thinking, its development and its impact on physics learning outcomes remain suboptimal. This gap can be

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attributed to the traditional teaching models, which are often monotonous and teacher-centered. Observations conducted at SMAN 1 Gerung reveal that teachers infrequently implement new interactive learning models, leading to student disengagement and a perception of physics as a complex and difficult subject, primarily due to the numerous concepts and formulas students must master (Nurul, 2022). This highlights the pressing need for innovative learning models that not only foster creative thinking but also improve student learning outcomes.

In response to this need, the Project-Based Learning (PjBL) model emerges as a promising alternative. PjBL actively involves students in solving real-world problems, both individually and collaboratively, through scientific processes within a designated period, and culminates in the production of tangible products that can be shared and communicated (Kemendikbud, 2020; Wahyudianti & Qurniati, 2022). Studies have shown that PjBL significantly enhances student learning outcomes by fostering collaborative learning and the creation of products that align with the subject matter being studied (Ismatulloh et al., 2020; Colim et al., 2022).

Unlike traditional models, which emphasize rote memorization and passive learning, PjBL promotes the development of creative thinking by focusing on the process of problem-solving throughout the project (Sulisworo, 2019; Rehman et al., 2024). It provides students with opportunities to explore, evaluate, interpret, and synthesize information meaningfully, fostering critical thinking, cooperation, and scientific inquiry (Musdalifah et al., 2023; Saepudin, 2020). Purnomo and Ilyas (2019) further highlight that PjBL encourages students to engage with the material through various methods and experiments, which enables them to solve complex problems collaboratively and develop their scientific attitudes.

The novelty of this study lies in its focus on the effect of the PjBL model specifically on the development of creative thinking skills in physics education, which has been inadequately explored in the context of Indonesian high school students. Creative thinking skills are critical in subjects like physics, where students are expected not only to grasp complex concepts but also to innovate and apply these concepts to solve real-world problems (MZ et al., 2021; Dias-Oliveira et al., 2024). This study is one of the first to explore how PjBL can be employed to enhance these skills in physics and to improve overall student learning outcomes.

The importance of this research stems from several compelling reasons. First, it addresses the need for innovative teaching methods in physics education that foster not only academic knowledge but also essential life skills, such as creative problem-solving and critical thinking, which are key to success in the 21st century (Iskandar et al., 2022). Second, by focusing on the PjBL model, this study provides insights into how project-based learning can overcome the limitations of traditional, teacher-centered approaches that are prevalent in many classrooms. Finally, the research aligns with the broader educational goal of improving student engagement and learning outcomes in science subjects, particularly physics, which remains a challenging subject for many students.

This study is expected to contribute to the development of more effective teaching strategies that integrate active learning with the development of essential skills, ultimately enhancing the quality of physics education and preparing students to face the challenges of a rapidly evolving world. By focusing on energy sources as the core material in Phase E of class X at SMAN 1 Gerung, this research targets a fundamental and relevant topic in physics education, aiming to improve both conceptual understanding and creative thinking in students.

Method

This study uses a quasi-experimental type with a Nonequivalent Control Group design. Quasi-experimental research aims to find a causal relationship between two or more variables. However, it cannot fully control external variables that affect the experiment (Sugiyono, 2020). This design allows researchers to see the effect of treatment on the experimental group compared to the control group. The research variables used consist of independent variables and dependent variables. The independent variable in this study is the Project Based Learning (PjBL) model.

In contrast, the dependent variables are creative thinking skills and student learning outcomes. The research design uses a Nonequivalent Control Group Design, which involves two groups: the experimental group and the control group. The experimental group was given treatment using the Project Based Learning (PjBL) model.

In contrast, the control group used a conventional learning model. Both groups will be given a pre-test and post-test to see the effect of the treatment. This research design allows researchers to compare the changes between the two groups by looking at the differences in pre-test and post-test results. This research was conducted from July 2023 until the completion of the research report. The location of the research was class X at SMAN 1 Gerung in the 2023/2024 academic year. The research population included all 342 students of class X of SMAN 1 Gerung divided into 11 classes. The cluster sampling technique was used to determine the sample, with class X-E (36 students) as the control class and class X-F (35 students) as the experimental class. The research procedure consisted of planning, implementation, and completion stages. In the planning stage, the researcher determined the research title, conducted a literature study, conducted observations at SMAN 1 Gerung, prepared a proposal, and created research tools and instruments. The implementation stage included determining the research sample, testing the instrument, implementing the pre-test, learning with the PjBL model in the experimental class and conventional learning in the control class, and implementing the post-test. In the final stage, the researcher processed and analyzed the data, drew conclusions, provided suggestions, and prepared a research report.

$$r_{xy}=\frac{N\sum XY-(\sum X)(\sum Y)}{\sqrt{\{N\sum X^2-(\sum X)^2\}\{N\sum Y^2-(\sum Y)^2\}}} \quad (1)$$

$$r_{11}=\left(\frac{n}{n-1}\right)\left(1-\frac{\sum\sigma_i^2}{\sigma_t^2}\right) \quad (2)$$

Information:

r_{xy}	:	The correlation coefficient between variable Y and variable X.
X	:	Score of test items
Y	:	The total score for each question
$\sum XY$	:	The number of times x is multiplied by y
$\sum X$	:	Sum of x
$\sum Y$	:	Sum of y
$\sum X^2$	:	The sum of the squares of x
$\sum Y^2$	:	The sum of the squares of y
N	:	The number of data
r_{11}	:	Calculated reliability
n	:	The number of questions
σ_t^2	:	total variance
$\Sigma\sigma_t^2$	:	The amount of variance for each question item

The research instrument was a creative thinking skills test and learning outcomes. The creative thinking skills test consisted of 5 essay questions, while the learning outcomes test consisted of 20 multiple-choice questions. Data were collected through pre-tests and post-tests conducted before and after treatment to determine the treatment's initial conditions and effects. The research instrument was tested for validity and reliability. The validity test used the product moment correlation formula to determine the validity of the test items (Equation 1). The reliability test used the Cronbach Alpha equation (Equation 2) for essay questions and Kuder Richardson (KR-20) for multiple-choice questions. Arikunto (2013) stated that the difficulty of the test is determined by its ability to evaluate the proportion of students who can provide correct answers. The complexity of essay test questions can be assessed using Equation 3.

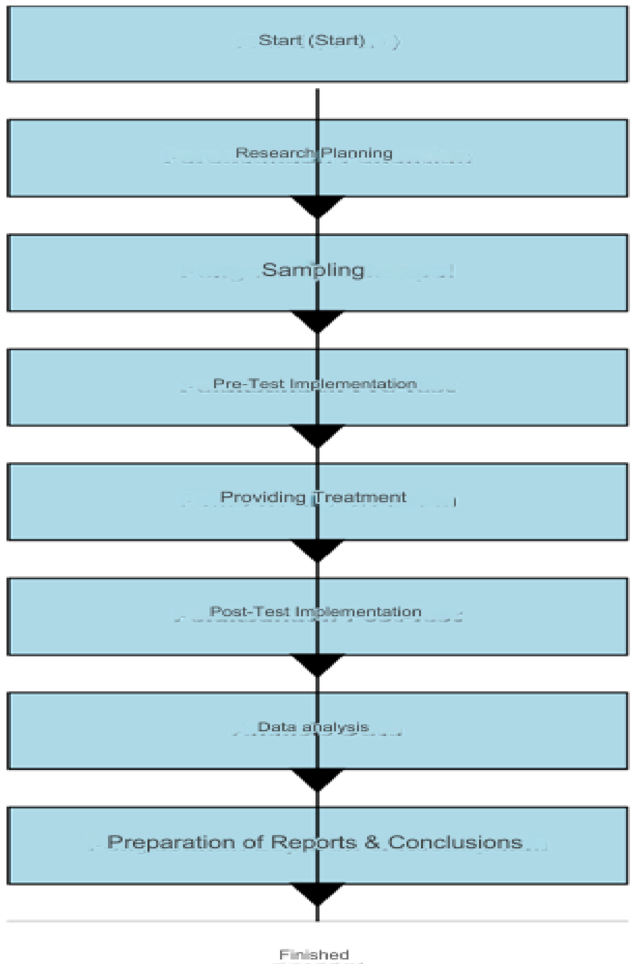

Figure 1. Research Implementation Flow

In contrast, for multiple-choice questions using Equation 4, the categorization of the question difficulty index is described in Table 1. The differential strength of the question is its ability to distinguish students with different proficiency levels, identifying individuals with higher levels of skills from those with lower skills. The discriminatory power of essay test questions is determined using the formula in Equation 5 and for multiple-choice questions using Equation 6. The classification of the question discriminatory power index is presented in Table 2.

$$TK=\frac{SA+SB}{IA+IB} \quad (3)$$

$$P=\frac{B}{JS} \quad (4)$$

$$DP = \frac{SA - SB}{IA} \quad (5)$$

$$DP = \frac{Ba}{Ja} - \frac{Bb}{Jb} = P_A - P_B \quad (6)$$

Information:

TK	:	Question difficulty level
SA	:	The cumulative score of the higher-tier category
SB	:	The cumulative score of the lower-tier category
IA	:	The total ideal score of the higher-tier category
IB	:	The ideal score for the lower-tier category
DP	:	Level of differentiation of questions
SA	:	The total score of the higher-tier category
SB	:	The total score of the lower-tier category
IA	:	The total ideal score of the higher-tier category
P		difficulty index
JS		the total number of test takers
B		the number of students who answered the test correctly

Tabel 1. Question Difficulty Index Classification

Question difficulty level	Category
0.00 ≤ TK ≤ 0.30	Hard
0.30 < TK ≤ 0.70	Medium
0.71 < TK ≤1.00	Easy

(Arikunto, 2013)

Tabel 2. Differential Power Index Classification

Level of differentiation	Category
0.00 – 0.20	Not good
0.21 – 0.40	Pretty good
0.41 – 0.70	Good
0.71 – 1.00	Very good

(Arikunto, 2013)

The difficulty level test uses a specific formula to determine the difficulty level of the questions. The differential power test uses the differential power formula to determine the ability of the questions to distinguish between high and low-ability students. Data analysis is carried out in several stages. The normality test is carried out to determine whether the data is usually distributed using the chi-square formula. The homogeneity test uses the F test to determine the homogeneity of the sample. Hypothesis testing uses MANOVA to test the effect of the PjBL model on creative thinking skills and learning outcomes. The MANOVA test requires dependent variables associated with each other, the assumption of homogeneity of variance-covariance that is met, and dependent variables that are usually distributed. With this structured research method, it is hoped that the research can provide valid and reliable results to measure the effect of the Project Learning model on students' creative thinking skills and physics learning outcomes.

Result and Discussion

Result

Creative Thinking Skills Data Description

Creative thinking skills data describes the skills in the psychomotor domain of students, especially creative thinking skills. This data was obtained through the pre-test and post-test results given to the experimental and control classes in the form of 5 descriptive questions that had been tested and analyzed. The pre-test aims to determine the initial abilities of students before being given treatment. In contrast, the post-test aims to determine the increase in skills after being given different treatments in the two classes. Based on the study's results, the average pre-test value of students' creative thinking skills in the experimental class was 42.58, while in the control class, it was 37.41. The average post-test values of creative thinking skills in the experimental and control classes were 76.29 and 67.77, respectively. These data show that the initial abilities of students in the two classes do not have significant differences so they can be categorized as the same. However, there was a higher increase in creative thinking skills in the experimental class compared to the control class after being given treatment. This indicates that using the project-based Learning (PjBL) model is more effective in improving creative thinking skills than conventional learning models.

Figure 2. Simple water wheel

Figure 3. Utilization of used cooking oil to make lamps

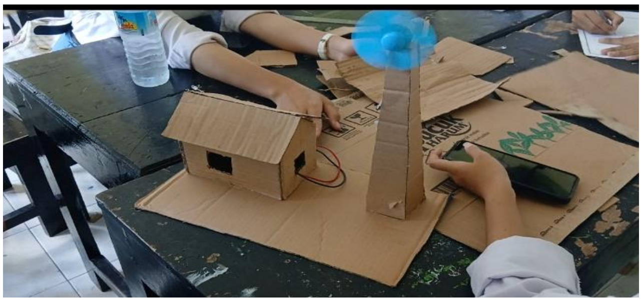

Figure 4. Wind Power Plant

Student Learning Outcome Data

Student learning outcome data covers the cognitive, affective, and psychomotor domains. For the cognitive domain, data was obtained through a pre-test and post-test through 15 multiple-choice questions that had been tested and analyzed. Meanwhile, learning outcome data in the affective and psychomotor domains were obtained through observation during the learning process.The results showed that the average pre-test value of physics learning outcomes in the experimental class was 40.55, while in the control class, it was 38.76. The average post-test value of learning outcomes in the experimental and control classes were 75.65 and 62.16, respectively. These data showed a higher increase in physics learning outcomes in the experimental class compared to the control class. This shows that the Project Based Learning (PjBL) model is more effective in improving student learning outcomes than conventional learning models.

In the affective domain, learning outcomes are measured based on specific criteria on the teacher's observation sheet. The indicators assessed include discipline, honesty, ability to express opinions, cooperation, and responsibility. The observation results showed that the average value in the experimental class was 3.39 with the criteria of "very good," while in the control class, it was 2.94 with the criteria of "good." This shows that the Project Based Learning (PjBL) model is also more effective in improving learning outcomes in the affective domain. In the psychomotor domain, learning outcomes are measured based on specific criteria in the observation sheet. The indicators assessed in the experimental class include skills in preparing tools and materials, assembling and using tools and materials, analyzing observation data, and presenting observation data. In the control class, the indicators assessed included systematic skills in answering discussion questions, interaction between group members, creativity during discussions, expressing opinions during group discussions, and creativity during presentations. The observation results showed that the average value in the experimental class was 3.43 with the criteria of "very good," while in the control class, it was 3.00 with the criteria of "good." This shows that the Project Based Learning (PjBL) model is more effective in improving learning outcomes in the psychomotor domain.

Pre-Test Results Data for Creative Thinking Skills and Learning Outcomes

The pre-test data were analyzed using the normality and homogeneity tests. The normality test was conducted to determine whether the initial data from both classes were usually distributed. The normality test results showed that the data on creative thinking skills and learning outcomes in both classes were usually distributed. This is indicated by the calculated X^2 value, which is smaller than the X^2 table, namely 3.57 and 3.61 for creative thinking skills and 4.02 and 3.66 for learning outcomes, all smaller than the X^2 table value of 11.070. The homogeneity test was conducted to determine the initial abilities of students in both classes before being given treatment. The results of the homogeneity test showed that both classes were homogeneous. This is indicated by the calculated F value, which is smaller than the F table, namely 1.35 for creative thinking skills and 1.27 for learning outcomes, all of which are smaller than the F table value of 1.869.

Post-Test Results Data for Creative Thinking Skills and Learning Outcomes.

The Post- test data were analyzed using the normality and homogeneity tests. The normality test was conducted to determine whether the final data from both classes were usually distributed. The normality test results showed that the data on creative thinking skills and learning outcomes in both classes were usually distributed. This is indicated by the calculated X^2 value, which is smaller than the X^2 table, 4.00 and 3.39 for creative thinking skills and 4.33 and 3.57 for learning outcomes, all smaller than the X^2 table value of 11.070. The homogeneity test was conducted to determine whether the variance of creative thinking skills and learning outcomes is homogeneous. The results of the homogeneity test showed that both classes are homogeneous. This is indicated by the calculated F value, which is smaller than the F table, which is 1.242 for creative thinking skills and 1.038 for learning outcomes, all of which are smaller than the F table value of 1.869.

Hypothesis Testing

Hypothesis testing was conducted to determine the effect of the treatment given on creative thinking skills and student learning outcomes. The final test scores of both classes were analyzed using parametric statistics, namely MANOVA, because the final test scores of both classes met the requirements of parametric statistical tests, namely being normally distributed and homogeneous. The results of the hypothesis test analysis showed that the Project Based Learning (PjBL) model significantly affected creative thinking skills and student learning outcomes. This is indicated by the significance value of 0.047 in the Pillae Trace, Wilk Lambda, Hotelling Trace, and Roy's Largest Root tests, all smaller than the significance level of 0.05. Thus, the alternative hypothesis (Ha) is accepted, and the null hypothesis (Ho) is rejected, which means that there is an effect of the Project Based Learning (PjBL) model on creative thinking skills and student learning outcomes.

Table 3. Manova Test Results

Sig. (MANOVA)	Significant Level	Criteria
0.047	0.050	H_a accepted

Discussion

The Influence of the Project Based Learning (PjBL) Model on Creative Thinking Skills and Learning Outcomes

Data on creative thinking skills were obtained from the pre-test and post-test results. The pre-test was used to determine the initial abilities of students. In contrast, the post-test was used to see the increase in creative thinking skills after treatment. Based on the pre-test data analysis, the average value of the experimental class was 42.58, and the control class was 37.41. These data indicate that the initial abilities of the two classes are the same because the data is normally distributed and homogeneous.

After being given treatment, the average post-test value of the experimental class's creative thinking skills increased to 76.29, while the control class only reached 67.77. These results indicate that the PjBL model is more effective in improving creative thinking skills than conventional learning models. Hypothesis testing using MANOVA showed a significance value <0.05, which means that there is a significant effect of the PjBL model on students' creative thinking skills. This is in line with the research of Habibi et al. (2020), which explains that PjBL is very effective in improving critical thinking skills.

Creative thinking skills have four indicators: fluency, flexibility, originality, and elaboration. Before treatment, low creative thinking skills were caused by conventional learning models and lack of practice. However, after being treated with the PjBL model, a significant increase occurred because this model stimulated students' creativity through group projects, presentations, and discussions. This is in line with research by Maysyaroh et al. (2021) and Chintya et al., (2023), which shows that the PjBL model has a significant influence on improving creative thinking skills. The PjBL model has a significant influence because it actively involves students in learning. Research by McKinney (2023) states that the PjBL Model significantly increases students' involvement and active participation in learning. This process involves students completing real projects requiring problem-solving, collaboration, and creativity. According to Dewi (2020), the PjBL model allows students to explore and discover the concepts they are learning for themselves, thereby increasing their involvement and interest in learning. Putri and Dwikoranto (2022) explained that implementing PjBL improves students' collaboration and problem-solving skills. Through these projects, students learn to work together and solve problems faced in real-world contexts, leading to significant improvements in these skills. Yanti et al (2023) and Musa et al. (2012) proved that PjBL has also been shown to increase students' creativity. In various studies, implementing PjBL has shown an increase in students' creative and innovative thinking skills, which are essential aspects of 21st-century education.

The learning outcomes of students were also analyzed through pre-test and post-tests. The pre-test results showed an average score of 40.55 for the experimental class and 38.76 for the control class, indicating that both classes had the same initial abilities. After being given treatment, the average post-test score of the experimental class increased to 75.65, while the control class only reached 62.16. These results indicate that the PjBL model is more effective in improving physics learning outcomes than conventional learning models. Hypothesis testing with MANOVA showed a significance value <0.05, which means that there is a significant effect of the PjBL model on student learning outcomes. The difference in learning outcomes in the cognitive domain is caused by applying the PjBL model, which is more interactive and motivates students to learn concretely and creatively. This model also changes students' perceptions that physics is a difficult and boring subject (Lobszowski et al., 2021; Pucher & Lehner, 2011). Improvements in learning outcomes are also seen in the affective and psychomotor domains. In the affective domain, students in the experimental class showed more positive attitudes such as responsibility, cooperation, and higher curiosity compared to the control class. In the psychomotor domain, students in the experimental class were more active in carrying out projects and presentations, which improved their practical skills. This study shows that the PjBL model improves learning outcomes in the cognitive domain and the affective and psychomotor domains. Guo et al. (2020) & Selasmawati & Lidyasari (2023), found that PjBL significantly improved critical thinking skills and cognitive learning outcomes, especially in science and technology. PjBL also improves the affective domain, such as students' motivation and emotional involvement in the learning process. Students involved in PjBL showed higher interest in learning and greater active participation (Nukak et al., 2021; Zouganeli et al., 2014). PjBL also significantly affected the psychomotor domain, where students showed improvements in practical skills and motor abilities. Studies show that PjBL improves psychomotor learning outcomes through projects requiring practical skills, such as workshop technology and applied science courses (Herlambang et al., 2023). These results are consistent with the research of Nurhikmayati & Sunendar (2020), Amalia et al., (2024), and Ilafi et al., (2024), which shows that the PjBL model improves creativity and student learning outcomes. Based on the results of the analysis, it was found that the project-based learning (PjBL) model has a significant effect on creative thinking skills and student learning outcomes. The application of this model makes students more creative and active and shows an increase in psychomotor skills. Thus, applying PjBL can improve creative thinking skills and student learning outcomes. The results of the hypothesis test analysis showed a significance value of 0.047, which is smaller than 0.05, indicating a significant effect on creative thinking skills and learning outcomes.

The PjBL model has a significant influence because it provides opportunities for students to learn through direct experience and reflection. According to Purnomo & and Ilyas (2019), project-based learning allows students to develop critical and creative thinking skills and improve their ability to collaborate and communicate. This is very different from conventional learning models that are more teacher-centered and less actively involve students.

Based on the results of this study, several suggestions can be given for further research. First, this study can be expanded by involving more schools and classes to increase the generalizability of the findings. Second, further research can examine the effect of the PjBL model on other subjects besides physics to see if the same results can be obtained. Third, this study can be improved by using mixed methods to understand students' experiences better using the PjBL model.

In addition, further research can explore other factors that can influence the success of the PjBL model, such as the role of teachers, facility support, and student learning motivation. Research can further examine how the PjBL model can be integrated with digital technology to improve learning effectiveness. Thus, this research can contribute more comprehensively to developing innovative and effective learning models.

Conclusion

This study shows that the the implementation of the Project-Based Learning (PjBL) model significantly enhances high school students' creative thinking skills and overall learning outcomes in physics education. The experimental class, taught using the PjBL model, showed a notable improvement in creative thinking (from 42.58 to 76.29) compared to the control class (from 37.41 to 67.77). Additionally, the PjBL model positively impacted students' cognitive, affective, and psychomotor outcomes, with the experimental class scoring higher in post-tests and exhibiting increased engagement, responsibility, and collaboration. These results support the effectiveness of PjBL in fostering creativity, critical thinking, and practical skills, aligning with previous research that highlights the benefits of interactive and student-centered learning approaches. This study contributes to the body of research on innovative teaching methods and suggests that incorporating PjBL in curricula can better prepare students for the complexities of the modern world, promoting not only academic success but also essential life skills.

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Author Contributions
Conceptualization; D. L; methodology; A. D.; validation; M. T.; formal analysis; S. R.; investigation.; D. L; resources; A. D.; data curation: M. T.; writing-original draft preparation. S. R.; writing-review and editing: D. L; visualization: a. D. All authors have read and agree to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict og interest.

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