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ORIGINAL RESEARCH

The effect of the creative problem-solving learning model on students' problem-solving skills and self-regulation in light wave learning

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Abstract
This study aims to examine the effect of the Creative Problem Solving (CPS) learning model on students' problem-solving skills and self-regulation in learning light wave material. The study employed a quasi-experimental design using a posttest-only control group design. The population consisted of all class XI science students at SMA Negeri 4 Tasikmalaya, Indonesia. The sample was selected using cluster random sampling, resulting in two groups: an experimental class and a control class, each consisting of 38 students. Data were collected through a problem-solving skills test in the form of seven validated essay questions based on Polya's problem-solving framework and a self-regulation questionnaire based on Zimmerman's self-regulated learning framework. Data were analyzed using Multivariate Analysis of Variance (MANOVA) after conducting prerequisite tests, including multivariate normality and homogeneity tests. The results of the analysis showed a significant difference between the experimental and control classes ($p < 0.05$) in terms of the combined dependent variables. Students who participated in CPS-based learning demonstrated higher problem-solving skills and self-regulation compared to those who experienced conventional learning. These findings suggest that the CPS learning model may support the development of students' cognitive and self-regulatory abilities in physics learning, particularly in abstract topics such as light waves.

Keywords: Creative Problem Solving (CPS) · Problem-Solving Skills · Self-Regulation · Light Waves · Physics Education.

INTRODUCTION

Education plays an important role in developing individuals' potential and preparing them to face future challenges. In the context of 21st-century education, learning is expected not only to focus on knowledge acquisition but also to develop essential skills that enable students to respond to rapidly changing social and technological environments. One widely recognized framework in modern education is the 4C skills, which include creative thinking, critical thinking and problem solving, communication, and collaboration (Ministry of Education and Culture, 2017; OECD, 2019). These competencies are considered essential because they help students analyze problems, generate ideas, and apply knowledge in real-world situations.

Among these competencies, problem-solving skills play a central role in science learning. Problem solving enables students to apply conceptual understanding when encountering unfamiliar situations and scientific phenomena. Previous studies have reported that students with strong problem-solving abilities tend to demonstrate better critical thinking and creativity

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in learning activities (Anderson et al., 2021). However, research in physics education shows that many students still experience difficulties when solving conceptual and analytical problems, particularly when they are required to integrate conceptual understanding with mathematical reasoning (Heller et al., 1992; Azizah et al., 2015).

This issue was also identified in physics learning at SMA Negeri 4 Tasikmalaya. A preliminary study conducted through classroom observations and interviews with physics teachers indicated that many students experienced difficulties in solving physics problems, especially in the topic of light waves, which involves abstract concepts and mathematical representations. Previous research in STEM-based science learning reported that students could identify problems and analyze their impacts, indicating that CPS helps students recognize and define scientific problems systematically (Nuraziza & Suwarma, 2018). Classroom observations showed that the learning process was still predominantly teacher-centered, with greater emphasis on the use of formulas and procedural calculations. As a result, students had limited opportunities to actively engage in problem analysis, explore alternative strategies, or reflect on their understanding when solving physics problems.These conditions indicate the need for instructional approaches that can support students in developing more effective problem-solving skills in physics learning. Therefore, this study investigates the use of the Creative Problem Solving (CPS) learning model as a strategy to facilitate students' engagement in problem-solving processes and improve their learning outcomes in light wave material.

Although several studies have reported the effectiveness of the Creative Problem Solving (CPS) model in improving students' creativity and problem-solving abilities, limited research has examined its simultaneous effect on students' problem-solving skills and self-regulation in physics learning, particularly in abstract topics such as light wave. In addition, self-regulation also plays an important role in student learning success. Self-regulation is the ability to control thoughts, feelings, and behavior in order to achieve predetermined learning goals. Previous research has shown that students' self-regulated learning can be enhanced through structured learning strategies, such as Writing to Learn, which also significantly improve cognitive achievement in science topics (Riyadi, Sinaga, & Siahaan, 2023). Research shows that good self-regulation is closely related to improved problem-solving skills (Zimmerman, 2022). These skills can be acquired through learning approaches that support the development of metacognition and active behavior in learning.To overcome this problem, a more innovative learning approach is needed that can develop both skills simultaneously. One model that can be applied is Creative Problem Solving (CPS). The CPS model guides students to think creatively in solving problems and helps them plan and evaluate solutions systematically. Research by Helen (2022) shows that the application of the Creative Problem Solving (CPS) model in physics learning can improve students' problem-solving and self-regulation skills, as this model provides space for students to be more actively involved in the learning process.

To overcome this problem, a more innovative learning approach is needed that can develop both skills simultaneously. One model that can be applied is Creative Problem Solving (CPS). The CPS model guides students to think creatively in solving problems and helps them plan and evaluate solutions systematically. The implementation of CPS has been shown to improve students' problem-solving abilities and metacognitive awareness, which reflects aspects of self-regulation in learning (Handayani & Rahmawati, 2021). Research by Helen (2022) shows that the application of the Creative Problem Solving (CPS) model in physics learning can improve

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students' problem-solving and self-regulation skills, as this model provides space for students to be more actively involved in the learning process.

Thus, this study aims to evaluate the effect of applying the Creative Problem Solving (CPS) model on students' problem-solving and self-regulation skills, particularly in light wave material. This study is expected to contribute to the development of effective learning models and improve the quality of student learning outcomes in schools. Based on the above background, the researcher will apply the Creative Problem Solving (CPS) learning model to light wave material in class XI MIPA by conducting a study entitled "The Effect of the Creative Problem Solving (CPS) Learning Model on Students' Problem-Solving Skills and Self-Regulation in Light Wave Motion Material".

METHODS

This study employed a quasi-experimental research design using a posttest-only control group design, and the sampling technique used was cluster random sampling, which randomly selected two classes from the population. The population of this study consisted of all students of class XI IPA at SMA Negeri 4 Tasikmalaya. The selected classes were divided into two groups, experimental class and control class each consisting of 38 students. The experimental class received learning using the Creative Problem Solving (CPS) model, while the control class received conventional learning.The stages of the research procedure are illustrated in Figure 1.

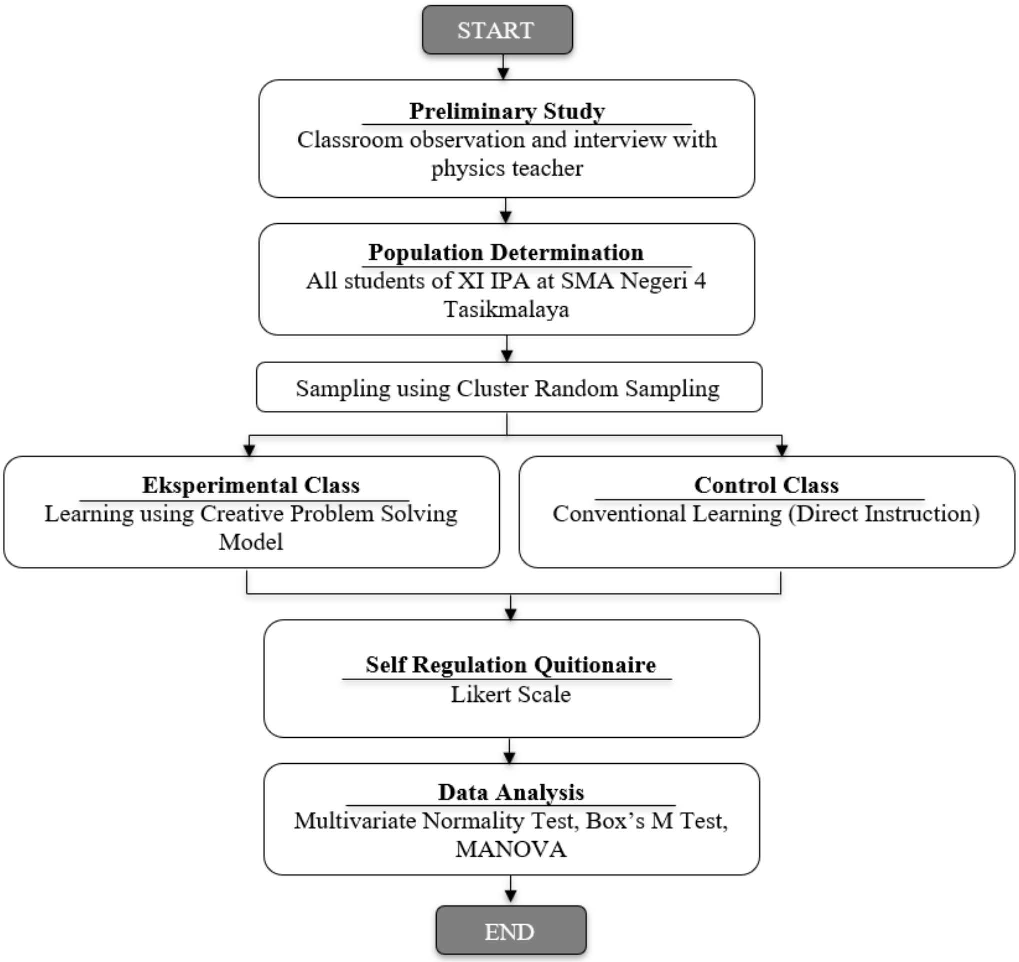

Figure 1. Reseach produce of the quasi-experimental study

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Data was collected through tests and surveys. The test instrument consisted of essay questions administered through a posttest to measure students' problem-solving skills based on Polya's problem-solving framework, which includes understanding the problem, devising a plan, carrying out the plan, and evaluating the solution. Meanwhile, the survey was conducted using a Likert-scale questionnaire to measure students' self-regulation after participating in the learning process, based on Zimmerman's self-regulated learning framework, which includes metacognition, motivation, and behavior.

Before being used in the study, the research instruments were tested to ensure their validity. Instrument validity testing was conducted using product moment correlation analysis to determine the empirical validity of each test item. In addition, content validity was evaluated by expert validators using Aiken's V coefficient. The product moment correlation coefficient was calculated using the equation 1.

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

Meanwhile, equation 2 is used for expert judgment validation analysis.

$$V = \frac{\sum s}{n\left(c-1\right)} \tag{2}$$

with, V = the respondent agreement index regarding the validity of the item; s = the score set by the respondent minus the lowest score (s = r - 1); r = the category score chosen by the respondent n = number of respondents; and c = number of categories filled in by respondents. In addition, the *self-confidence* questionnaire scoring refers to Table 1.

Table 1 Questionnaire Scoring

Statement	Positive	Negative
Strongly Agree (SA)	4	1
Agree (A)	3	2
Disagree (D)	2	3
Strongly Disagree (SD)	1	4

To determine the consistency of the instruments to be used, an instrument reliability test was conducted using the Cronbach's alpha using the equation 3.

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sum \sigma_t^2}\right) \tag{3}$$

The range of values that can be interpreted based on the index according to Guilford (1956) is presented in Table 2.

Table 2 Interpretation of Reliability Test

Range	Interpretation
$0.00 < r_{11} \leq 0.20$	Very low
$0.20 < r_{11} \leq 0.40$	Low
$0.40 < r_{11} \leq 0.60$	Moderate

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Range	Interpretation
$0.60 < r_{11} \leq 0.80$	High
$0.80 < r_{11} \leq 1.00$	Very High

The prerequisite tests in this study included multivariate normality tests using the Mahalanobis distance test and multivariate homogeneity tests using Box's M test. The hypothesis test used was the MANOVA (Multivariate Analysis of Variance) test. The MANOVA statistical test has several types, including Pillai's Trace, Wilks' Lambda, Hoteling's Trace, and Roy's Largest Root. The calculations were assisted by using IBM SPSS software version 25.

The results showed that the Aiken's V values for the problem-solving test items ranged from 0.83 to 0.92, indicating that all items were in the valid category. Furthermore, empirical validity testing was conducted using the Pearson Product Moment correlation test. The results showed that all seven essay items had correlation coefficients higher than the critical value, indicating that the items were statistically valid.

The reliability of the instruments was tested using Cronbach's Alpha coefficient. The analysis showed that the reliability coefficient of the problem-solving skills test was $\alpha = 0.87$, which falls into the high reliability category. Meanwhile, the self-regulation questionnaire obtained a Cronbach's Alpha value of $\alpha = 0.91$, indicating very high reliability. These results indicate that the instruments used in this study are valid and reliable for measuring students' problem-solving skills and self-regulation.

RESULTS

Creative Problem Solving Posttest Result

The experimental class received treatment with the application of the Creative Problem Solving (CPS) model, while the control class used the Direct Instruction model. Both classes were given the same material, namely light waves. To measure students' problem-solving and self-regulation skills, both classes were given 7 questions and 25 questionnaire statements. The descriptive statistics of students' problem-solving skills and self-regulation in the experimental and control classes are presented in Table 3.

Table 3 Posttest Results for the Experimental Class and Control Class

Score	Creative Problem Solving		Self-Regulation	
	E	C	E	C
Highest	96	88	92	89
Lowest	52	35	38	49
Average	19.10	18.77	71.63	70.44
Standard Deviation	11.03	15.47	12.82	11.16

Table 3 shows that the mean score of students' problem-solving skills in the experimental class is higher than that of the control class. A similar pattern is also observed in students' self-regulation scores. These descriptive results indicate that students who participated in learning using the Creative Problem Solving (CPS) model tended to achieve better outcomes compared to those who experienced conventional learning. In addition, the standard deviation values indicate that the distribution of problem-solving scores in the experimental class is relatively more concentrated around the mean compared to the control class.

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Before conducting hypothesis testing, several prerequisite tests were carried out to ensure that the data met the assumptions required for multivariate analysis. The multivariate normality test was conducted using the Mahalanobis distance approach calculated using SPSS version 25 software. The basis for decision making was a significance level of less than 5% or 0.05. The results of the correlation between Mahalanobis distance values and Chi-square values are presented in Table 4.

Table 4 Multivariate Normality Test Results

Class	Data	Statistical test Mahalanobis test	Chi-Square test	Conclusion
Experimental Class	*Pearson Correlation*	1	0,991	
	Sig.		< 0.001	
	N	38	38	Sig < 0.05 (Normally Distributed)
Control Class	*Pearson Correlation*	1	0,967	
	Sig.		< 0.001	
	N	38	38	

Multivariate normality was tested using the Mahalanobis distance approach by examining the correlation between Mahalanobis distance values and Chi-square values. The results showed a very strong and significant correlation for the experimental class ($r = 0.991$, $p < 0.001$) and the control class ($r = 0.967$, $p < 0.001$). The significance values obtained were less than 0.05, indicating that the data in both classes were normally distributed. The homogeneity of the variance-covariance matrices was tested using Box's M test in SPSS version 25. The decision rule stated that if the significance value was greater than 0.05, the data were considered homogeneous. The results of the test are presented in Table 5.

Table 5 Homogeneity Test Results

Statistical Test	Results	Conclusion
Box's M	4,045	Significance value > 0.05 (Homogeneous Data)
F	1,332	
Sig.	0,152	

Table 5 shows that the significance value of Box's M is 0.152, which is greater than 0.05. Therefore, the variance-covariance matrices of the dependent variables can be considered homogeneous. After the prerequisite assumptions were satisfied, hypothesis testing was conducted using Multivariate Analysis of Variance (MANOVA) to examine the effect of the Creative Problem Solving (CPS) model on students' problem-solving skills and self-regulation simultaneously. The results of the MANOVA test are presented in Table 6.

Table 6 Hypothesis Test Results

Effect	MANOVA test	$F_{calculation}$	F_{table}	Sig.
CPS	*Hotteling's Trace*	108,957	1,74	0,000

Table 6 shows that the significance value obtained from the MANOVA test is 0.000, which is less than 0.05. In addition, the calculated F value (108.957) is greater than the F table value (1.74). Therefore, the null hypothesis (H_0) is rejected. This result indicates that there is a statistically significant difference between the experimental and control classes in terms of the combined dependent variables, namely students' problem-solving skills and self-regulation.

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The findings of this study are consistent with the results of the preliminary study conducted at SMA Negeri 4 Tasikmalaya. The preliminary study, which involved classroom observations and interviews with physics teachers and students, indicated that students experienced difficulties in solving physics problems and in managing their learning processes. These difficulties were also reflected in the results of students' final semester assessments, where many students did not achieve the minimum passing criteria. These conditions suggest that students' problem-solving skills and self-regulation in learning still need improvement.

Based on these conditions, this study investigated the implementation of the Creative Problem Solving (CPS) learning model as an instructional approach that may support the development of students' problem-solving skills and self-regulation. The CPS model emphasizes several stages, including problem clarification, idea generation, evaluation and selection of solutions, and implementation. These stages are closely related to the indicators of problem-solving skills, such as understanding the problem, planning strategies, implementing strategies, and evaluating solutions. Therefore, the CPS learning model may facilitate students in engaging more systematically in the problem-solving process (Prastika, 2023).

In this study, the implementation of the CPS model in the experimental class was supported by the use of CPS-based student worksheets (LKPD), which were designed to guide students through each stage of the problem-solving process. These worksheets helped structure learning activities and encouraged students to actively participate in analyzing and solving physics problems.

The results of the posttest on problem-solving skills showed that students in the experimental class obtained higher scores compared to those in the control class. This finding suggests that the CPS learning model may contribute to improving students' ability to analyze problems, develop solution strategies, and evaluate the results of their problem-solving processes. These findings are consistent with previous research indicating that the CPS model can support the development of students' problem-solving abilities in learning contexts (Hartiwi, 2021; Prastika, 2023).

Furthermore, the results of the self-regulation questionnaire analysis showed that the experimental class also obtained higher scores compared to the control class. This indicates that students who participated in CPS-based learning tended to demonstrate better self-regulation in terms of metacognitive awareness, motivation, and learning behavior. The CPS learning process provides opportunities for students to reflect on their thinking processes and learning strategies, which may support the development of self-regulated learning. The average percentage of students' self-regulation levels for each indicator is presented in the Table 7.

Table 7 Percentage of Each *Self-Regulation* Indicator

Class	**Indicator**	**Percentage**
	Metacognitive	72.3
Experimental	Motivation	72.4
	Behavior	69.4
Average		71.4
	Metacognitive	71.6
Control	Motivation	69.4
	Behavior	69.1
Average		70.0

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The results presented in Table 7 indicate that students in the experimental class demonstrate higher levels of self-regulation compared to those in the control class. This result may be related to the learning activities implemented through the Creative Problem Solving (CPS) model. The CPS learning stages encourage students to engage systematically in identifying problems, generating ideas, evaluating solutions, and implementing selected strategies. These learning processes may support the development of students' metacognition, motivation, and learning behavior. Previous research has indicated that self-regulated learning strategies significantly contribute to the development of creative problem-solving skills, suggesting that students who actively regulate their cognitive, metacognitive, and resource management processes are more likely to enhance their problem-solving abilities through structured instructional strategies (ElAdl & Polpol, 2020).

Furthermore, the CPS learning syntax is closely related to the indicators of problem-solving skills and self-regulation, as students are required to analyze problems, plan solution strategies, and reflect on the results of their learning process. These activities may contribute to the development of more effective learning regulation among students. In contrast, learning in the control class was conducted using direct instruction, which tended to be more teacher-centered. In this learning approach, students primarily received explanations from the teacher with fewer opportunities to actively explore ideas or engage in problem-solving activities. This difference in learning experiences may explain why the posttest results of students in the experimental class were higher than those in the control class.

CONCLUSION

Based on the results of this study, it can be concluded that the implementation of the Creative Problem Solving (CPS) learning model has a significant effect on students' problem-solving skills and self-regulation in learning light wave material in class XI science students at SMA Negeri 4 Tasikmalaya. The findings show that students who participated in CPS-based learning achieved higher levels of problem-solving skills and self-regulation compared to students who experienced conventional learning. These results are in line with international studies indicating that CPS is more effective in improving students' creative thinking and communication skills when accompanied by high levels of self-regulated learning. These results indicate that the CPS learning model may serve as an effective instructional approach to support the development of both cognitive and self-regulatory skills in physics learning. However, further research involving larger samples and different educational contexts is recommended to confirm and extend these findings.

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