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Students' creative thinking in physics: An investigation of the effectiveness of the CPS instructional model

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Abstract

This experimental study investigates the effectiveness of the Creative Problem Solving (CPS) instructional model in enhancing creative thinking skills among high school physics students, with particular focus on the challenging topic of sound waves. Employing a rigorous quasi-experimental design with pretest-posttest control group methodology, the research involved 60 eleventh-grade students from SMAN 5 Padang, Indonesia, evenly divided into experimental and control groups. The experimental group participated in CPS-based learning activities that emphasized problem exploration, idea generation, and solution refinement, while the control group received conventional teacher-centered instruction. Quantitative analysis revealed statistically significant improvements in the experimental group's creative thinking scores (M=73.83) compared to the control group (M=60.43), with a strong t-test result ($t=9.76$, $p<0.05$). The intervention yielded a moderate normalized gain score ($g = 0.50$) and a remarkably large effect size ($d = 2.59$), particularly in the creative thinking indicators of fluency (the ability to generate multiple ideas) and flexibility (the capacity to approach problems from diverse perspectives). Complementary qualitative data from classroom observations and student interviews provided rich insights into the learning process, documenting enhanced student engagement, increased confidence in expressing novel ideas, and greater willingness to explore unconventional solutions to physics problems. Students reported appreciating the structured yet open-ended nature of CPS activities, which allowed them to connect abstract sound wave concepts to real-world applications. These compelling findings position CPS as a valuable pedagogical approach for physics education, effectively bridging the gap between content mastery and the development of creative skills.

Keywords: Creative problem solving, Creative thinking, Fluency and flexibility, Instructional innovation, Physics education.

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1. Introduction

In today's rapidly evolving technological landscape, educational systems face increasing demands to cultivate 21st-century skills, particularly creative thinking [1, 2]. Physics education presents unique challenges in this regard, as it requires students to comprehend abstract concepts and apply them to complex, real-world phenomena [3]. Despite the growing recognition of the importance of creativity, traditional physics instruction often emphasizes rote memorization and algorithmic problem-solving, neglecting opportunities for creative engagement [4]. This gap is especially evident in Indonesian classrooms, where national curriculum goals emphasizing scientific creativity frequently clash with conventional teaching practices [5].

Preliminary research at SMAN 5 Padang revealed alarming deficiencies in students' creative thinking abilities, with over 60% scoring in the "non-creative" range on standardized measures. Classroom observations confirmed that instruction predominantly focused on formulaic problem-solving, offering few opportunities for idea generation or open-ended exploration. This disconnect between curricular aspirations and classroom reality underscores the urgent need for pedagogical interventions that can effectively nurture creative thinking in physics education. The Creative Problem Solving (CPS) model has demonstrated promise in various educational contexts [6-8]. Empirical studies examining its application to high school physics, particularly in Indonesia, remain scarce. Existing research has not sufficiently addressed how CPS can be adapted to teach abstract physics concepts such as sound waves, nor has it comprehensively measured the model's impact on all dimensions of creative thinking (fluency, flexibility, originality, and elaboration). This study aims to fill these critical gaps in the literature.

This study investigates three primary research questions: First, it examines whether the CPS model enhances students' creative thinking skills in physics compared to conventional instruction. Second, it explores which specific aspects of creative thinking (fluency, flexibility, originality, and elaboration) demonstrate the most significant improvement through CPS implementation. Third, the study analyzes how students perceive and engage with CPS-based learning activities in their physics classroom. To address these questions, the research employs a comprehensive mixed-methods approach that combines a quasi-experimental design with pretest-posttest control groups to quantitatively measure differences in creative thinking scores, along with classroom observations and student interviews to capture qualitative insights about the learning process. Additionally, the study incorporates rubric-based analysis of creative outputs to systematically evaluate student progress across all four creative thinking indicators. Through this multifaceted methodology, the research generates both empirical evidence and practical guidance for effectively integrating creativity-focused pedagogies into physics education, ultimately contributing to more robust preparation of students for the complex cognitive demands of modern scientific inquiry and problem-solving.

2. Theoretical Foundations

2.1. Creative Thinking in Education

Creative thinking is increasingly acknowledged as a core competency in 21st-century education [9, 10]. It refers to the cognitive ability to generate novel and useful ideas, solutions, or products [11]. In educational contexts, particularly in science and physics learning, creativity plays a vital role in problem-solving, hypothesizing, modeling, and applying concepts to real-world phenomena [3]. Include creativity in the "4Cs" framework; critical thinking, communication, collaboration, and creativity are essential for modern learners to thrive in complex and unpredictable environments.

The characteristics of creative thinking have been described and operationalized by several scholars. One of the most widely cited frameworks was developed by Treffinger et al. [12] who proposes four core indicators: fluency, or the ability to generate multiple relevant ideas; flexibility, the ability to produce different categories or perspectives of responses; originality, the ability to produce uncommon or novel ideas; and elaboration, the ability to expand on or develop ideas in detail. These indicators are often used as assessment criteria to measure students' creative performance across subjects, including science.

Despite its importance, creative thinking is often underrepresented in traditional instructional models. Many teachers, especially in content-heavy subjects like physics, focus on procedural knowledge and right-or-wrong answers, neglecting opportunities for divergent thinking [13-17]. A study by. Further emphasized that the structure of schooling tends to limit student choice, exploration, and creative risk-taking, thus reducing the chances for students to engage creatively with learning materials [18].

2.2. Challenges in Teaching Physics Creatively

Physics education presents a unique challenge for the development of creativity. The abstract nature of many physics concepts, such as wave-particle duality, electric fields, or the behavior of sound, requires not only understanding but also imagination. According to Duit and Treagust [19], many students find physics difficult because it involves visualizing phenomena that cannot be directly observed and connecting them with mathematical representations.

In Indonesia, the situation reflects similar challenges. The physics curriculum outlined in the national educational framework emphasizes conceptual understanding, scientific reasoning, and problem-solving. However, research indicates a significant gap between curriculum expectations and actual classroom implementation [20]. Teachers often rely on lectures and textbook exercises, which rarely stimulate higher-order thinking or creative engagement with content.

Empirical data from the preliminary study in this research further confirms this gap. A needs analysis conducted with 25 students from SMAN 5 Padang revealed alarmingly low levels of creative thinking. Based on instruments adapted from Treffinger's framework, the students' average creative thinking score was only 8.33%, with most students scoring below 15% and falling into the "non-creative" category. In addition, classroom observations and interviews with teachers confirmed that instruction predominantly focused on mastering formulas and answering test-like questions, with little emphasis on idea generation or open-ended problem-solving [21].

2.3. Instructional Models for Promoting Creativity

Recognizing the limitations of traditional instruction, numerous educational theorists and practitioners advocate for the adoption of student-centered, inquiry-based models that foster creativity. One promising approach is Creative Problem Solving (CPS), a model originally developed by Alex Osborn and Sidney Parnes and further refined by Treffinger and colleagues [22-25]. CPS offers a structured yet flexible process for generating and implementing innovative solutions to problems, making it highly relevant for educational settings aiming to cultivate creative thinkers. The CPS model typically comprises six stages, grouped into three major components:

Understanding the Challenge (Objective finding, Fact finding, Problem finding),

Generating Ideas (Idea finding),

Planning for Action (Solution finding, Acceptance finding).

Each phase involves both divergent thinking, where many possibilities are explored, and convergent thinking, where ideas are evaluated and refined. This dual process is designed to simulate real-world innovation practices and is particularly effective for tasks requiring both creativity and critical judgment. Numerous studies support the effectiveness of CPS in enhancing creative thinking. For instance, Al-Abdali and Al-Balushi [26] found that middle school science teachers who implemented CPS strategies observed significant improvements in their students' ability to propose novel hypotheses and explain scientific phenomena using creative analogies [27, 28]. Reported similar results in engineering education, where CPS helped students develop solutions to design problems that required both scientific accuracy and inventive thinking.

2.4. CPS and Physics Learning

The application of CPS in physics instruction holds considerable promise due to its alignment with the goals of scientific inquiry and problem-solving. Physics problems often require students to move beyond simple algorithmic approaches and instead explore multiple pathways to arrive at a solution. The open-ended structure of CPS encourages this exploration, allowing students to engage with the material in a way that fosters deeper understanding and more personal investment.

For example, when learning about sound waves, students can be challenged to invent methods for visualizing wave behavior using everyday materials. Through CPS stages, they would define the challenge, brainstorm creative methods (such as using water surfaces, phone apps, or slinky springs), evaluate feasibility, and test their designs. This process not only promotes content mastery but also nurtures students' capacity for flexible thinking and problem ownership.

In the current study, the topic of sound waves was deliberately chosen due to its abstract nature and high potential for creative exploration. Students in the experimental group were guided through CPS phases as they solved contextual problems, such as designing soundproof environments, exploring resonance in musical instruments, or detecting sound frequency using improvised tools. These tasks required them to employ all four indicators of creative thinking, from generating multiple ideas to elaborating and refining their solutions.

2.5. Assessing Creative Thinking in Physics

Measuring creativity in educational settings is inherently complex, as it involves both cognitive and affective dimensions. However, several validated rubrics and instruments have been developed to assess the specific components of creative thinking. In this study, the assessment rubric was adapted from Treffinger's model and tailored to the context of physics learning. Each student's response was evaluated on:

Fluency: The number of relevant ideas generated.

Flexibility: The variety of strategies or approaches used.

Originality: The uniqueness of the idea about peers.

Elaboration: The depth, detail, and logical flow of the explanation.

The rubrics were used to score students' responses to open-ended physics tasks before and after the intervention. To ensure reliability, inter-rater scoring was conducted, and Cronbach's alpha was calculated. Preliminary analysis showed high internal consistency, with alpha values exceeding 0.8, indicating that the instrument was both reliable and appropriate for measuring creative thinking in this context.

Moreover, classroom observations during the intervention phase provided qualitative data on students' engagement, collaboration, and creative risk-taking. Many students who were previously passive became actively involved in group discussions, proposed unconventional solutions, and expressed greater confidence in articulating their ideas. These observations support the claim that when given structured opportunities, students are capable of thinking creatively, even in subjects traditionally perceived as rigid or formulaic.

2.6. Theoretical Significance and Educational Implications

The integration of CPS into physics learning aligns with several learning theories. From a constructivist perspective, CPS supports knowledge construction through active exploration, reflection, and collaboration [29]. The model also resonates with Vygotsky's socio-cultural theory, which emphasizes the role of social interaction and scaffolding in the development of higher-order thinking. By working in groups and engaging in dialogue, students not only learn from their peers but also extend their creative capabilities through shared meaning-making.

From a cognitive perspective, CPS enhances both divergent and convergent thinking processes, which are central to problem-solving in physics. Fosnot and Perry [29] revision of Bloom's taxonomy places "creating" at the highest cognitive level outcome that the CPS model is explicitly designed to achieve. By fostering conditions where students can explore, evaluate, and refine ideas, CPS operationalizes this theoretical goal in practical classroom activities.

Therefore, the theoretical foundations for using CPS in physics education are robust. It aligns with established psychological theories, supports national curriculum goals, and addresses the documented weaknesses in current classroom practices. Furthermore, it empowers both teachers and students to redefine the physics classroom as a space for inquiry, creativity, and intellectual discovery.

3. Methodology

This study employed a quasi-experimental design using a non-equivalent control group pretest-posttest model, aimed at investigating the effectiveness of the Creative Problem Solving (CPS) instructional model in enhancing students' creative thinking in physics. The design was chosen due to its suitability for natural classroom settings where random assignment is not feasible, but comparison between groups is essential [30].

3.1. Participants

The participants of this study were students from class XI Fase F at SMAN 5 Padang, Indonesia, during the second semester of the academic year 2023/2024. The population consisted of eight parallel classes. Two classes were selected purposively based on their similar academic background, demographic characteristics, and prior physics achievement as provided by the school's guidance and counseling unit. One class was designated as the experimental group and taught using the CPS instructional model, while the other served as the control group and was taught using traditional instruction based on direct explanation and textbook-based exercises.

Each group consisted of 30 students, resulting in a total of 60 participants. All students were within the age range of 16 to 17 years and had previously studied basic wave concepts in physics. Before the intervention, both groups were pretested to establish baseline creative thinking levels, and posttested afterward to assess improvement and effectiveness.

3.2. Instruments

The primary instrument used in this study was a creative thinking test in physics, developed and validated by the researcher. The test comprised five open-ended items aligned with the topic of sound waves, designed to measure the four indicators of creative thinking: fluency, flexibility, originality, and elaboration. Each item was scored using a rubric scale from 0 to 4, where: 0 = no response or irrelevant; 1 = emerging indicator; 2 = partial presence of indicator; 3 = appropriate and relevant response; 4 = excellent demonstration of the indicator.

To ensure the instrument's validity, it was reviewed by two physics education experts and one curriculum specialist. Content validity was further confirmed using Aiken's V index, resulting in a score of 0.85, indicating high agreement among experts. For reliability, a pilot test was conducted on a group of 20 students not involved in the main study. The internal consistency of the test was measured using Cronbach's Alpha, yielding a value of 0.82, which is considered high reliability [31].

In addition to the test, qualitative data were obtained through classroom observation sheets and semi-structured interviews with several students and the physics teacher to gain deeper insights into the learning process and students' engagement [32].

3.3. Procedure

The intervention was conducted over six weeks, with each group receiving a total of 12 hours of instruction. The experimental group was taught using the CPS instructional model, structured around the three main components: understanding the challenge, generating ideas, and planning for action [33]. Lessons were designed around real-life problems related to sound waves, such as how to reduce noise pollution in classrooms or how to construct a simple musical instrument that demonstrates resonance.

In the understanding of the challenge phase, students identified problems and explored related information. In the generating ideas phase, students brainstormed multiple solutions without judgment, promoting divergent thinking. In the planning for action phase, they selected the most feasible solutions and elaborated on how to implement them, encouraging convergent thinking and detailed planning [34]. Meanwhile, the control group followed the standard curriculum using a direct instruction model, which involved teacher explanation, textbook readings, and individual practice questions without collaborative or open-ended problem-solving activities. To maintain consistency and minimize teacher effects, the same teacher taught both groups, using lesson plans tailored to the respective models. Both groups were pretested one week before the intervention and posttested one week after the final session.

The students' test scores were analyzed both quantitatively and qualitatively [35]. For quantitative analysis, the pretest and posttest scores were compiled and analyzed using descriptive statistics (mean, standard deviation) and inferential statistics (paired-sample t-tests and independent t-tests). The effect size was calculated using Cohen's d to determine the magnitude of the impact of CPS instruction on students' creative thinking. Furthermore, inter-rater reliability was assessed for the test scoring. Two independent raters evaluated the responses, and the inter-rater reliability index using Cohen's Kappa was found to be 0.78, indicating substantial agreement [36-39]. For qualitative data, student and teacher reflections, as well as observations, were analyzed thematically to explore patterns in student engagement, collaborative behavior, and evidence of creative expression during learning activities [18]. Ethical procedures were observed throughout the study.

Informed consent was obtained from school authorities, students, and their parents. The identity of participants was kept confidential, and participation in the study did not affect students' formal academic grades.

4. Results

This section presents the results of the study, including descriptive and inferential statistics of the pretest and posttest scores, gain score analysis, comparison between the experimental and control groups, as well as observations and qualitative feedback from students. The focus is on evaluating how the implementation of the Creative Problem Solving (CPS) model impacted students' creative thinking skills in the topic of sound waves in a senior high school physics class.

4.1. Descriptive Statistics

The creative thinking test was administered as a pretest and posttest to both the experimental group (taught using CPS) and the control group (taught using traditional methods). The test consisted of five open-ended questions, each targeting four core indicators of creative thinking: fluency, flexibility, originality, and elaboration.

Pretest Results

The pretest aimed to determine the baseline level of students' creative thinking before the intervention. The results showed that students in both the experimental and control groups demonstrated low levels of creative thinking.

Table 1.
Pretest Result.

Group	N	Mean	Standard Deviation
Experimental Group	30	47.70	6.90
Control Group	30	48.37	7.04

The pretest scores indicate a relatively comparable starting point between the two groups, with no statistically significant difference at the 5% level (t-test result: $t = -0.367$; $p > 0.05$). This suggests that both groups had similar creative thinking abilities before the intervention.

4.2. Posttest Results

After the instructional intervention, posttest results revealed a notable difference between the two groups.

Table 2.
Posttest Result.

Group	N	Mean	Standard Deviation
Experimental Group	30	73.83	5.52
Control Group	30	60.43	4.76

The increase in mean scores for the experimental group demonstrates a significant improvement in creative thinking. An independent t-test conducted on the posttest scores confirmed a statistically significant difference in favor of the experimental group ($t = 9.76$; $p < 0.05$), indicating the effectiveness of the CPS instructional model.

4.3. Gain Score Analysis

To quantify the learning gain from pretest to posttest, the normalized gain score (g) was calculated for each student using Hake's formula. The average gain scores were as follows:

Table 3.
Gain Score Analysis.

Group	N	Mean Gain Score
Experimental Group	30	0.50
Control Group	30	0.25

This result indicates that students in the experimental group achieved a moderate improvement, while the control group showed only a low level of gain. This further supports the conclusion that the CPS model contributed positively to the development of creative thinking.

4.4. Indicator-Specific Performance

To understand which components of creative thinking were most affected by the intervention, scores for each of the four indicators, fluency, flexibility, originality, and elaboration, were analyzed separately.

Table 4.
Indicator-Specific Performance.

Indicator	Experimental Posttest Mean	Control Posttest Mean
Fluency	15.53	11.77
Flexibility	15.00	11.70
Originality	14.67	12.10
Elaboration	14.63	11.90

The most significant differences between the groups were observed in the indicators of fluency and flexibility, suggesting that the CPS model particularly encouraged students to generate and vary their ideas. Originality and elaboration also showed improvement, though to a slightly lesser extent. The implication is that CPS, by emphasizing ideation and action planning, aligns well with fluency- and flexibility-focused tasks.

4.5. Distribution of Creative Thinking Categories

The post-intervention categorization of students' creative thinking levels revealed significant differences between the experimental and control groups. In the experimental group, a notable 60% of students (n=18) achieved high levels of creative thinking (scores ≥75), demonstrating mastery across all four indicators of creative thinking. This substantial proportion of high performers was complemented by 33% (n=10) reaching moderate levels (scores 60-74), while only 7% (n=2) remained in the low performance category (<60). These results stand in stark contrast to the control group's distribution, where only 7% (n=2) attained high creative thinking levels, while half of the students (50%, n=15) showed moderate performance, and a concerning 43% (n=13) remained at low levels.

This categorical analysis provides compelling evidence for the CPS model's effectiveness in elevating students' creative capacities. The experimental group's distribution skewing strongly toward high-performance categories suggests that CPS instruction not only improves average scores but also enables a majority of students to reach advanced creative competency levels. The control group's distribution pattern, with most students clustered in moderate and low categories, mirrors findings from conventional physics classrooms reported in recent studies [40-43]. The dramatic 53-percentage-point difference in high achievers between groups (60% vs. 7%) particularly highlights CPS's potential to transform typical performance distributions in physics education.

These findings gain additional significance when considering the baseline equivalence of both groups, as established by pretest scores. The transformation from relatively uniform starting points to dramatically different outcome distributions strongly suggests that the CPS intervention, rather than pre-existing differences, caused the observed performance enhancements. The results align with but substantially extend previous research by demonstrating not just mean score improvements, but complete restructuring of the performance distribution toward higher creative thinking levels. This distributional analysis provides crucial insights for educators, showing that CPS can move entire classrooms toward higher creative performance benchmarks rather than simply producing marginal improvements at the group mean level.

4.6. Effect Size Analysis

The magnitude of the intervention's impact was quantified through Cohen's d analysis, revealing an exceptionally large effect size ($d = 2.59$). This calculation was derived from the experimental group's substantial posttest mean score of 73.83 compared to the control group's 60.43, with a pooled standard deviation of 5.17. Such an effect size substantially exceeds conventional benchmarks in educational research, where $d = 0.8$ is typically considered large. The extraordinary magnitude of this effect suggests that the CPS intervention did not merely produce statistically significant results but rather generated transformative improvements in students' creative thinking capabilities.

When contextualized within recent meta-analyses of pedagogical interventions in science education, this effect size stands out as particularly remarkable. Most educational innovations typically yield effect sizes ranging from 0.4 to 0.8, making the current finding of 2.59 exceptionally noteworthy. This suggests that CPS may represent one of the most potent interventions for developing creative thinking in physics education. The effect size's magnitude also implies practical significance; students exposed to CPS instruction demonstrated creative thinking abilities nearly 2.6 standard deviations above their conventionally taught peers, a difference that would be visible in classroom practice.

The robustness of this effect is further underscored when compared with similar studies employing creativity-focused interventions. While recent work reported moderate effect sizes ($d = 0.6$-1.2) for various creativity programs, and found $d = 1.4$ for arts-integrated science instruction, our results demonstrate substantially greater impact. This discrepancy may be attributed to the unique synergy between CPS's structured ideation techniques and the particular demands of physics problem-solving, particularly for abstract concepts like sound waves. The finding challenges prevailing assumptions about the modifiability of creative thinking in secondary science education, suggesting that with appropriate pedagogical support, students can achieve dramatically higher creative performance than conventional instruction typically produces.

4.7. Observational Findings

Classroom observations were conducted during the six-week intervention period. Observers noted that students in the experimental group were significantly more engaged and participatory. They frequently worked in teams to brainstorm ideas, discussed alternative approaches to problems, and demonstrated enthusiasm during creative activities such as designing experiments or constructing conceptual models. Teachers reported that students began to ask more exploratory questions and showed increased interest in connecting physics concepts with real-life scenarios. In contrast, students in the control group mostly remained passive, only responding to teacher questions or completing individual assignments.

4.8. Student Interviews and Reflections

Interviews conducted with six randomly selected students from the experimental group revealed consistent themes. Students appreciated the opportunity to "think freely," "work in groups," and "try different ways to solve a problem." One student stated:

“Before, I was afraid to give ideas because I thought they would be wrong. But with CPS, we are encouraged to say anything first and evaluate later. That made me more confident.”

Another student mentioned that the hands-on nature of CPS helped them understand the concept of resonance more deeply:

We had to create a model of a musical instrument and explain how it makes sound. I used a plastic bottle and rubber bands. It was fun, and I finally understood resonance.

These responses illustrate how the CPS model not only improved cognitive performance but also positively affected students’ motivation, confidence, and enjoyment of physics learning.

4.9. Summary of Results

The findings of this study demonstrate that the CPS instructional model had a significant and positive effect on students’ creative thinking abilities in physics. Quantitative data showed significant increases in test scores, gain scores, and creative thinking indicators. The experimental group outperformed the control group in all aspects of assessment. Qualitative data supported these results, highlighting increased student engagement, confidence, and creativity in the classroom.

These results align with previous research indicating that CPS is effective in fostering higher-order thinking skills and validate its applicability in the physics classroom, especially for abstract topics such as sound waves.

5. Discussion

This section presents an in-depth analysis of the findings from the implementation of the Creative Problem Solving (CPS) instructional model in improving students' creative thinking skills in physics. The discussion is structured into several sub-sections: interpretation of statistical results, comparison between groups, indicator-based analysis, gain score implications, and integration of qualitative observations. Furthermore, the results are discussed in the light of relevant theories and findings from previous research.

5.1. Improvement in Creative Thinking: Quantitative Confirmation

The primary outcome of the study is the significant improvement observed in students’ creative thinking abilities following the implementation of the CPS model. The posttest mean score of the experimental group (73.83) was substantially higher than that of the control group (60.43). The independent t-test result ($t = 9.76$; $p < 0.05$) confirms that this difference is statistically significant. This aligns with the findings of Al-Abdali and Al-Balushi [26], who demonstrated that students taught through creativity-oriented models in science classrooms showed a measurable increase in their ability to generate diverse and original responses. The result also supports those who asserted that instructional approaches promoting active engagement and structured problem solving are more effective in cultivating creative skills than traditional lecture-based methods.

The significant increase in creative thinking scores among students taught using CPS further affirms the argument of Dempsey et al. [33]. That creativity can be explicitly taught and enhanced through deliberate instructional processes. The systematic nature of the CPS model encourages students to explore problems openly, brainstorm solutions, and refine those ideas, which seems to provide the necessary cognitive scaffolding to foster creativity.

5.2. CPS vs Traditional Instruction: Bridging the Creativity Gap

The study reveals a stark contrast between students taught using the CPS model and those taught through conventional methods. While both groups started at similar levels of creative thinking, as evidenced by nearly identical pretest scores (47.70 vs. 48.37), the posttest revealed a substantial gap (13.4-point difference). Traditional instruction in the control group largely focused on teacher-centered methods, explanations, textbook questions, and procedural problem-solving, which are insufficient for cultivating higher-order cognitive skills. This observation is consistent with findings [44-46] who reported that such instruction tends to suppress opportunities for divergent thinking in science classrooms. On the other hand, the CPS model provides a structure that empowers students to construct their understanding, collaborate, and explore multiple possibilities. This kind of environment is aligned with constructivist learning theory, which advocates for learners to be active agents in constructing knowledge through authentic tasks.

5.3. Indicator-Based Analysis: Fluency and Flexibility Lead the Gains

Further insights were gained by analyzing students’ performance on each of the four creative thinking indicators: fluency, flexibility, originality, and elaboration. Among these, fluency (mean = 15.53) and flexibility (mean = 15.00) recorded the highest posttest means in the experimental group, indicating that the CPS model particularly enhanced students’ capacity to generate multiple and diverse ideas. Fluency and flexibility are fundamental aspects of divergent thinking, a core principle in CPS. During the "Idea Finding" phase, students are encouraged to propose as many solutions as possible, without judgment, which directly supports fluency. Simultaneously, considering different perspectives and alternatives during problem framing nurtures flexibility [25]. The indicators of originality (mean = 14.67) and elaboration (mean = 14.63), while slightly lower, also showed notable improvement. These aspects are stimulated in the "Solution Finding" and "Acceptance Finding" phases of CPS, where students must evaluate and refine their ideas and present them in detail. This aligns with the findings of Beghetto [47] and Beghetto and Kaufman [48], who emphasized the importance of structured refinement in promoting creative output that is not only novel but also contextually appropriate.

5.4. Gain Score Interpretation: Evidence of Learning Impact

The normalized gain score analysis further reinforces the positive impact of the CPS model. The experimental group recorded an average gain score of 0.50, categorized as moderate Hake [49], while the control group recorded only 0.25, categorized as low. This finding aligns with previous studies in science education that utilize active learning and CPS. For example, Aisyah and Kurniawan [50] demonstrated a similar gain pattern when implementing guided inquiry combined with creative exercises. The gain score reflects the capacity of a teaching model not just to deliver content but to build transferable thinking skills, a key attribute of 21st-century education.

5.5. Observational Data and Student Voice: Behavioral Evidence

Beyond test scores, classroom observations, and student interviews provided qualitative evidence supporting the efficacy of the CPS model. Students in the experimental group exhibited active participation, collaborative problem solving, and increased willingness to share unconventional ideas. This change in classroom culture from passive to participative is one of the strongest indicators of effective creative instruction.

One student described how CPS encourages idea-sharing without fear of judgment. This freedom is essential in creative classrooms, where psychological safety must be preserved to support experimentation and innovation [51]. Additionally, students reported a better understanding of physics concepts such as resonance when they were involved in constructing models and engaging with real-world problems, demonstrating the dual impact of CPS on cognitive understanding and creative expression. These findings echo the work of Kabilan et al. [52] and Kabilan and Kamarudin [53], who found that student-centered, open-ended learning in science not only enhanced creativity but also increased confidence and motivation to learn.

5.6. Theoretical Linkages: Cognitive and Social Dimensions

The outcomes of this study strongly support cognitive theories of creativity, particularly [54]. Structure of Intellect Model, which links fluency, flexibility, and originality to specific intellectual operations [54]. It also affirms Vygotsky's social development theory, as CPS involves social interaction, scaffolding, and co-construction of ideas, which are essential for advancing learners through their zone of proximal development.

Moreover, the CPS model itself exemplifies Bloom's revised taxonomy, especially at the upper levels: analyzing, evaluating, and creating, which are often neglected in traditional instruction. By engaging students in planning, evaluating solutions, and constructing responses, CPS ensures that learning transcends rote acquisition and becomes generative.

5.7. Educational Implications

The results carry significant implications for physics education in Indonesia and similar contexts. First, they underscore the necessity of pedagogical innovation in subjects that are traditionally abstract and procedural. The success of the CPS model in this study suggests that creativity can and should be developed in science classes, not just in the arts or humanities. Second, the findings provide actionable insights for teacher training programs. Teachers need to be equipped not only with content knowledge but also with strategies for facilitating creativity in the classroom. This includes techniques for brainstorming, questioning, encouraging elaboration, and building a classroom culture that values novel ideas. Lastly, the study supports the inclusion of creative thinking assessment in classroom evaluations. By using rubrics that reflect fluency, flexibility, originality, and elaboration, educators can shift their focus from purely correct answers to the quality and diversity of student thinking, a move that better prepares students for the complexities of real-world problem solving.

Although the results of this study are promising, several limitations must be acknowledged. The sample size, limited to two classes in a single school, may restrict the generalizability of the findings. Additionally, the duration of the intervention, six weeks, might not fully capture the long-term development of creative thinking. Future research could explore longitudinal effects of CPS implementation, integrate digital tools to support creative engagement, or compare CPS with other models such as project-based learning or STEAM approaches. Mixed-methods studies that include deeper ethnographic data would also enrich the understanding of how creativity unfolds in real classroom settings.

6. Conclusions

This study provides compelling evidence that the Creative Problem Solving (CPS) instructional model serves as a transformative approach for developing creative thinking skills in physics education, particularly for abstract concepts such as sound waves. The robust experimental findings demonstrate that students exposed to CPS instruction achieved significantly higher creative thinking scores ($M=73.83$) compared to their conventionally taught peers ($M=60.43$), with this substantial 13.4-point difference being both statistically significant ($t=9.76$, $p<0.05$) and educationally meaningful, as evidenced by the remarkable effect size ($d=2.59$). These quantitative outcomes gain deeper significance when examined through the lens of creative thinking components, where fluency and flexibility showed particularly strong improvements, suggesting CPS's unique capacity to enhance idea generation and cognitive flexibility, precisely the skills most needed for tackling complex physics problems.

The research makes three fundamental theoretical contributions to science education. First, it successfully operationalizes creativity assessment in physics through the rigorous application of Treffinger's framework, demonstrating that creative thinking can be systematically developed and measured in STEM disciplines. Second, it positions CPS as a powerful bridge between cognitive and constructivist theories, illustrating how structured yet open-ended problem-solving activities can foster both divergent thinking and conceptual understanding simultaneously. Third, the study emphasizes the crucial sociocultural dimension of creativity development, showing how collaborative CPS activities create zones of proximal development where students' creative capacities expand through peer interaction and guided exploration.

For educational practice, these findings carry important implications across multiple levels. Classroom teachers can leverage CPS to transform their physics instruction from formulaic problem-solving to authentic scientific inquiry, while curriculum developers should reconsider how creativity metrics can be embedded throughout science curricula. At the policy level, the results argue for substantial investments in teacher professional development focused on creativity-fostering pedagogies and for the redesign of assessment systems to value creative thinking alongside content mastery. Perhaps most significantly, the study reveals how CPS empowers students themselves, transforming their role from passive knowledge recipients to active creators and problem-solvers, a shift with profound implications for their academic identity and future STEM engagement.

Several limitations temper these positive findings and suggest directions for future research. The study's relatively small sample size from a single institution and brief intervention period (six weeks) warrant cautious generalization, while the focus on creative thinking alone leaves open questions about CPS's impact on other learning outcomes. Subsequent research should employ longitudinal designs with larger, more diverse samples to examine how creative gains persist and transfer across contexts. Additional studies could productively explore CPS adaptations for different STEM disciplines, technological enhancements for virtual learning environments, and implementations tailored for diverse learner populations.

Ultimately, this research contributes to a growing consensus that creativity development must move from the periphery to the center of science education. In an era of rapid technological change and complex global challenges, the ability to think creatively about scientific problems is not merely advantageous but essential. The demonstrated success of CPS in physics education suggests a path forward, one where abstract scientific concepts become springboards for creative exploration rather than obstacles to memorization. By embracing such approaches, educators can better prepare students not just to understand the physical world as we know it, but to imagine and create the scientific future we need.

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