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How do Science Teachers Implement Problem-Based Learning to Foster Students' Creative Thinking Skills? A Case Study in Middle Schools

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Abstract: Indonesian students' creative thinking skills, as assessed by PISA 2022, were significantly below the average. This study evaluated the implementation of problem-based learning (PBL) in supporting the development of creative thinking skills among students at SMP Negeri 2 Gamping, Yogyakarta. A qualitative approach with a case study design involved three science teachers and eighth-grade students. Data were collected through interviews, observations, and document analysis. Validity was analyzed through data triangulation (observations, interviews, and documentation) and peer discussions. The findings indicated that problem-based learning had a positive implementation, although significant challenges remained, such as insufficient planning, non-contextual teaching media, and limited scaffolding. The teachers frequently used simple investigations that did not fully encourage deep idea exploration. The assessment was predominantly summative and did not comprehensively evaluate students' creative processes. This study recommended a more structured problem-based learning approach, contextual teaching media, and process-oriented formative assessment to foster students' creativity. Further research was suggested to explore the long-term impact of this strategy and the integration of educational technology.

Keywords: contextual media, creative thinking skills, problem-based learning, science investigation, case study.

▪ INTRODUCTION

Creative thinking skills are crucial in 21st-century education to prepare students for increasingly complex global challenges (Villanova & Cunha, 2021). These skills encompass generating diverse, original, and contextually relevant ideas, flexibility in responding to dynamic changes, and innovation in creating new solutions (Thornhill-Miller et al., 2023; Ye & Xu, 2023). International organizations such as the OECD identify creativity as a key competency essential for individuals to support sustainable development and drive socio-economic progress in the future (OECD, 2023b). In the educational context, creative thinking skills enable students to acquire knowledge and solve problems innovatively (Abdulla Alabbasi et al., 2021; Amrina et al., 2024; Duval et al., 2023).

According to the PISA 2022 results of the OECD, Indonesia is among the 14 lowest-performing countries in creative thinking skills. Indonesian students scored an average of 19 out of 60, significantly below the OECD average of 33 (OECD, 2024). Only 31% of Indonesian students reached at least Level 3 (basic proficiency) in creative thinking, compared to the OECD average of 78%. Additionally, only 5% of Indonesian students were classified as high achievers in creative thinking (Level 5 or 6), whereas the OECD average is 27%. Leasa et al. (2021) found that most Maluku elementary students had only sufficient (66%) or low (33%) creativity. Amaliyah et al. (2023) reported an average creative thinking score of 49.87 in Surakarta, while Musdi et al. (2024) noted that over 50% of students at all education levels showed low creative thinking skills. These

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findings highlight a substantial gap in Indonesia's education system, particularly in fostering higher-order thinking skills among junior high school students (Tanudjaya & Doorman, 2020; Tasman, 2020).

The lack of creative thinking skills may hinder students' ability to compete internationally and contribute to national development, particularly in a knowledge-based economy (Daubaraite-Radikiene & Startiene, 2022; Yang & Zhao, 2021). According to the OECD (2023a), creative thinking skills involve the ability to generate diverse ideas, generate creative ideas, and evaluate and improve ideas. In science education, these skills are essential for helping students connect scientific concepts with real-world solutions (Sun et al., 2020). Furthermore, creative thinking skills enable students to understand natural phenomena through an investigative approach, fostering innovation in solving scientific problems (Yildiz & Guler Yildiz, 2021). creative thinking skills are crucial role in science learning, preparing students to face real-world challenges (Ye & Xu, 2023).

Various learning models that have advantages that can improve students' creative thinking skills in science according to the results of the study include inquiry-based learning (B. Panjaitan & Siagian, 2020), problem-based learning (Kiraga, 2023), project-based learning (Zulyusri et al., 2023), guided inquiry learning (Doyan et al., 2020), and contextual teaching and learning (Puji et al., 2024). PBL is an instructional approach that engages students in solving real-world problems, encouraging them to think critically and creatively (Barrows, 1986). According to the meta-analysis results, the PBL model in science learning dramatically improves students' creative thinking skills. It is more often researched because it has several advantages (Wiyanto et al., 2020; Zhan et al., 2024). PBL fosters creativity by engaging students in real-world problem-solving, encouraging idea generation, and promoting self-directed learning (Haryanto et al., 2024; Kiraga, 2023; Nasukha et al., 2022; Simanjuntak et al., 2021; Tan, 2009). Students consider the learning process of PBL to be more exciting and challenging (Kardoyo et al., 2020).

Numerous previous studies have analyzed instructional approaches that support creativity. A qualitative study by Haryani et al. (2021) in vocational high schools concluded that integrating creativity and innovation, critical thinking and problem-solving, collaboration, and communication in science classrooms was explored through surveys and group discussions. Meanwhile, Sukardi et al. (2022) explored the perspectives of junior high school science teachers on strategies for fostering student creativity in both urban and rural areas of Indonesia. Their findings revealed that teachers prioritized conceptual mastery over creativity, often adopting foreign strategies with minimal adaptation.

However, these studies have not explicitly examined how creative thinking skills are developed through structured instructional models in middle school science classrooms. Most existing research focuses on teacher perceptions or broad instructional approaches without directly measuring students' creative thinking outcomes. Additionally, while studies on problem-based learning (PBL) have highlighted its benefits for critical thinking and problem-solving, there is still a lack of empirical evidence on how PBL fosters creative thinking skills in the context of middle school science education. This study addresses these gaps by investigating the implementation of PBL in science learning and assessing its impact on students' creative thinking skills. By providing empirical data on the effectiveness of PBL, this study aims to inform instructional practices that explicitly nurture creativity in science education.

To bridge this gap, this study explores the implementation of PBL in science learning and evaluates its impact on students' creative thinking skills. It aims to inform instructional practices that nurture creativity in science education by providing empirical data. Building on these objectives, this study seeks to answer the following research questions:

1. How do science teachers implement problem-based learning to support students' creative thinking skills?
2. What challenges do science teachers face in implementing problem-based learning?
3. How do science teachers assess students' creative thinking skills in problem-based learning settings?

▪ METHOD

Participants

This school was selected because it represents the issue of low creative thinking skills among students. This study involved all science teachers at the school, consisting of three experienced science teachers and 29 eighth-grade students from SMPN 2 Gamping in Yogyakarta. They were chosen from a population of approximately 570 students. The participants were selected using purposive sampling to ensure representation of various academic abilities (Campbell et al., 2020). The teachers had over five years of science education experience and implemented problem-based learning (PBL) in their classrooms. Their experience with PBL came with several challenges, particularly in designing contextual problems and facilitating effective investigations. The students came from diverse academic backgrounds, allowing for an examination of how PBL fosters creativity across different proficiency levels.

Research Design and Procedures

This study employed a qualitative case study approach to examine students' creative thinking skills in problem-based science learning (Yin, 2018). For over four months, from September to December 2024, the research focused on work, energy, power, and simple machines. The data collection process began with a preliminary study in September to identify instructional practices, obtain ethical clearance, and select participants. In October, research instruments-including observation sheets, interview guides, and document analysis frameworks-were developed and validated. Data was collected in November through classroom observations, semi-structured interviews, and document analysis. Observations involved structured classroom observations using checklists and field notes to examine teacher-student interactions, scaffolding strategies, and student engagement in PBL, following the stages of problem orientation, organizing for learning, investigation, presentation, and evaluation (Arends, 2012). Semi-structured interviews with teachers and students explored teaching strategies, learning experiences, and challenges in PBL, with all interviews recorded via phone for accuracy and later transcribed for analysis. Document analysis focused on reviewing teachers' lesson plans and worksheets and assessing students' creative thinking skills, which were measured using essay-based tests designed by teachers following PISA indicators (OECD, 2023a). After data collection, data analysis was conducted in December to interpret and synthesize the findings systematically.

Instruments

This study utilized multiple data collection instruments based on Gagné's Nine Events of Instruction, with modifications by Iqbal et al. (2021). The instruments, including observation sheets, semi-structured interview guides, and documentation sheets, were validated through expert review to ensure alignment with the research objectives and clarity of wording. All instruments' content or construct validity was assessed by two science education experts with doctoral degrees before use. The content or construct validity of all instruments was assessed by two science education experts with doctoral degrees before use. Based on Borich's (2003) percentage agreement, a score of 89% was obtained, exceeding the 75% threshold, indicating that the instruments are suitable for use. The following table outlines the instrument framework:

Table 1. The instrument framework

Gagné stage	Category	Assessed Aspect	Instruments Indicator
1	Gaining attention	Engaging attention	The teacher uses strategies to capture students' attention at the beginning of the lesson.
2	Informing learners of objectives	Stating objectives	The teacher explains the relevance and benefits of the material to enhance student motivation.
3	Stimulating recall of prior learning	Activating prior knowledge Experience-based learning	The teacher connects new material with students' prior knowledge. The teacher engages students in real-world problem-solving.
4	Presenting the stimulus/PBL stage 1 & 2	Delivering content	The teacher encourages the application of problem-solving skills in daily life.
5	Providing learning guidance/PBL stage 3	Offering guidance Collaboration & discussion	The teacher supports students struggling with group work. The teacher assigns group projects, and students respond positively.
6	Eliciting performance/PBL stage 4	Practicing knowledge Active student participation Hypothesis testing & problem solving	The teacher provides feedback that supports students' emotional and academic growth. The teacher applies appropriate assessments for students' creative thinking skills (formative or summative). The teacher consistently uses creative assessments based on learning contexts.
7	Providing feedback	Giving feedback	The teacher uses preferred methods to relate lesson content to students' daily experiences.
8	Assessing performance/PBL stage 5	Evaluating performance	The teacher fosters teamwork skills in learning activities.

9	Enhancing retention & transfer	Retention & transfer	The teacher routinely integrates teamwork skills into lessons.
		Learning reflection	The teacher systematically facilitates student reflection on learning.

Data Analysis

Data validity was verified using data triangulation and peer discussions to ensure the credibility and reliability of the findings. Data triangulation was conducted through source triangulation and method triangulation (Miles et al., 2014). To identify consistencies and discrepancies, source triangulation involved comparing data from different participants, such as teachers, students, and documents. Method triangulation was applied by collecting data through multiple techniques, including interviews, observations, and document analysis, allowing for cross-verification of findings. Additionally, peer discussions were undertaken to refine data analysis and interpretation. After the initial coding process, findings were reviewed and discussed with peers to ensure consistency and accuracy. These discussions involved cross-checking interpretations, evaluating whether emerging themes aligned with the collected data, and addressing discrepancies. When differing perspectives arose, further analysis and discussions were conducted until a consensus was reached. The final refinements were then made based on peer feedback, strengthening the trustworthiness of the results. NVivo 12 software facilitated efficient data organization, categorization, and synthesis, enhancing the rigour of the analysis.

The analysis followed pattern matching (Yin, 2018), consisting of three stages: theory matching, identifying inconsistencies, and concluding patterns. In the first stage, theory matching, the collected data were aligned with existing theories on PBL and creative thinking skills, ensuring that interpretations were grounded in established research. The second stage, identifying inconsistencies, involved analyzing deviations from expected patterns and providing deeper insights into unique or unexpected findings. This step was crucial in refining interpretations and preventing over-reliance on pre-existing assumptions. Finally, key themes were synthesised in the concluding patterns stage to offer meaningful insights into how PBL influences students' creative thinking skills. To ensure credibility and accuracy, multiple validation strategies were employed. Data triangulation, incorporating observations, interviews, and document analysis, strengthened the validity of the conclusions by cross-verifying findings from multiple sources. Peer discussions enabled researchers to examine and refine interpretations, minimizing potential biases critically. Additionally, ethical considerations were upheld throughout the study, ensuring that the research process was conducted with integrity and that the findings accurately represented the role of PBL in fostering students' creative thinking development.

▪ RESULT AND DISSCUSSION

Implementation of Problem-Based Learning by Science Teachers to Support Students' Creative Thinking Skills

Science teachers implement problem-based learning (PBL) by incorporating hands-on investigations, such as measuring effort and power in lifting and moving objects. Mrs. Ye observed, "Students are highly engaged when conducting experiments, as they enjoy exploring concepts firsthand." Mrs An emphasized, "Group discussions help students exchange ideas and develop creativity."Meanwhile, Mrs Am stated, "I prefer to guide students gradually, starting with simple tasks before moving to complex ones." Teachers connect science concepts to real-life contexts like food and business to enhance engagement. However, lesson plan analysis reveals challenges, including insufficient support for struggling students, unclear group task distribution, and rigid time constraints that limit reflection. Students suggest more precise task instructions, more hands-on practice, and more subtantial motivational support.

While structured PBL steps problem orientation, investigation, presentation, and evaluation are followed, some students struggle with idea development and collaboration. Observations indicate that contextual learning and structured guidance enhance creativity, yet passive participation and ineffective media use remain issues. Mrs An noted, "Some students dominate discussions, while others hesitate to contribute." To optimize PBL for creative thinking, improvements are needed in worksheets, learning media, and task distribution. Three key themes emerge (see Figure 1): the role of contextual examples, structured PBL implementation, and the integration of emotional and academic support.

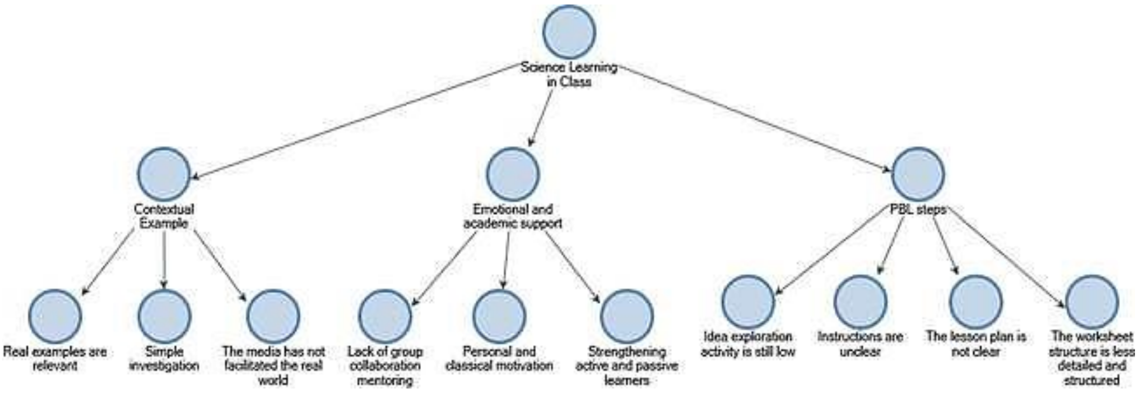

Figure 1. NVivo map results on science learning in the classroom

According to Figure 1, classroom science learning integrates contextual and problem-based approaches to enhance engagement and problem-solving skills. Using real-life examples has effectively connected scientific concepts to daily experiences (Kervinen et al., 2020). However, investigations remain too simple, and learning media have yet to fully facilitate real-world applications (Kong, 2021; Picardal & Sanchez, 2022). As a result, students struggle to think analytically and creatively, limiting their ability to generate and explore new ideas (Fredagsvik, 2023; Skjelstad Fredagsvik, 2022). Constructivist theories emphasize contextual learning as a way to deepen understanding (Piaget, 1978; Vygotsky, 1978). However, without structured scaffolding and open-ended tasks, the potential for creative thinking remains underdeveloped (Chang et al., 2024).

Findings from the NVivo Map Results on Science Learning in the Classroom highlight key challenges in PBL implementation. As shown in Table 2, before PBL implementation, only 8% of students demonstrated high creative thinking skills, while 68% remained in the low category. After PBL, the proportion of highly creative students increased to 14%, while those in the low category slightly decreased to 65%. Although this indicates improvement, most of students still struggled with critical and creative problem-solving. Task design, scaffolding strategies, and instructional support play a crucial role in determining the effectiveness of PBL. Unlike previous studies by (Kiraga, 2023; Nasukha et al., 2022; Simanjuntak et al., 2021), which reported a more substantial increase in creativity after PBL, this study suggests that the structured nature of classroom tasks and insufficient scaffolding may have limited students' ability to develop originality and elaboration in their ideas. According to Guilford (1967) creativity model, fluency and flexibility improved, but the lack of opportunities for open-ended problem-solving may have constrained originality and elaboration, which are critical aspects of creative thinking.

Further analysis suggests that teacher guidance and student collaboration are significant in PBL's success. Observations revealed that some students dominated group discussions while others remained passive, which may have limited opportunities for all students to develop creative thinking skills. Social constructivist theories suggest effective collaboration requires structured role assignments to ensure equitable participation (Vygotsky, 1978). Without proper guidance, passive participation increased, limiting opportunities for deep cognitive engagement and idea development (Tan, 2009). Additionally, students' prior learning experiences may have influenced their response to PBL. If students were accustomed to rote memorization and teacher-directed instruction, they may have struggled to adapt to the open-ended nature of PBL tasks. This aligns with research by Rahayuningsih et al. (2023), which found that students with little exposure to inquiry-based learning tend to exhibit lower cognitive flexibility, explaining why many students in this study remained in the low creative thinking category even after PBL implementation.

Beyond instructional design and classroom interactions, teachers also encountered various challenges in implementing PBL effectively. Factors such as heavy workload, time constraints, lack of adequate learning resources, and difficulties managing student engagement were key barriers. The following section will further explore these challenges, providing deeper insight into how external and internal factors influenced the success of PBL in the classroom. In conclusion, while PBL positively affected students' creative thinking skills, its impact was moderated by task structure, scaffolding, classroom collaboration, and instructional support. Compared to prior research, this study suggests that PBL alone is insufficient; it must be carefully designed with structured scaffolding, open-ended problem-solving, and active teacher facilitation to maximize creativity development. However, the extent to which these strategies can be effectively implemented depends on the challenges teachers face in real classroom settings, which will be discussed in the following section.

Challenges Faced by Science Teachers in Implementing Problem-Based Learning

Teachers face multiple challenges in fostering creativity due to high workloads and limited time for innovation. Administrative responsibilities force them to use practical over creative media. Mrs Ye and Mrs An noted the burden of 30 hours plus additional roles, making innovation difficult. Facility constraints also hinder hands-on learning laboratories are underutilized, and time limitations restrict the use of contextual learning media. As a result, teachers rely more on videos and simple media. Teachers often choose more straightforward methods rather than deep creative exploration in adapting to students' low confidence and academic ability. While students enjoy video-based learning, teachers observe fatigue affecting engagement, especially in the afternoon sessions. Group work also presents challenges some students dominate while others remain passive. Mrs Ye and Mrs An noted unequal participation, requiring constant teacher intervention.

Low motivation influenced by family background, economic conditions, and study habits is a key issue from the student's perspective. Mrs An and Mrs Am observed poor ASPD results and low interest in learning. Many students struggle with focus, critical thinking, and confidence. Fear of making mistakes discourages participation, with Student 3 stating, "I am afraid of being wrong, so I stay silent." Group work imbalances further hinder creativity, as less confident students avoid contributing while dominant ones take over tasks. Some enjoy investigations but struggle with explaining results, making problem-solving less effective. Observations highlight passivity in discussions, struggles with analytical tasks, and inconsistent group participation levels.

The challenges in implementing PBL can be categorized into two interrelated key themes (see Figure 2): challenges from students and teachers, each encompassing several specific difficulties.

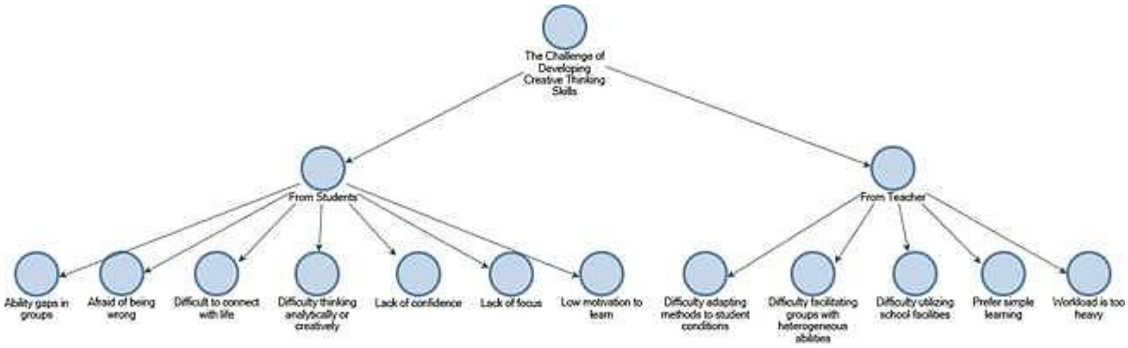

Figure 2. NVivo map results on the challenges of developing creative thinking skills

Science teachers face multiple barriers in implementing problem-based learning (PBL), including workload pressures, limited time, and inadequate facilities, which hinder their ability to foster students' creative thinking (Aguirre et al., 2022; Kim, 2019). Administrative burdens reduce opportunities for designing innovative lessons, leading teachers to rely on practical but less exploratory methods (Darling-Hammond et al., 2020). This aligns with Barrows' (1986) PBL model, which emphasizes the need for flexibility and scaffolding yet highlights a gap between theoretical expectations and real-world classroom conditions. Differentiated instruction remains a significant challenge as teachers struggle to adapt PBL activities to students' diverse abilities (Iterbeke et al., 2020). While differentiation is crucial (Tomlinson, 2001),, limited professional development and time constraints hinder effective implementation (Hasanah et al., 2022). Unlike previous studies that found teachers overcoming workload constraints through collaborative planning (Kim, 2019), this study suggests that a lack of structured professional training limits teachers' ability to integrate PBL effectively. Reducing administrative tasks, implementing co-teaching models, and providing structured PBL training can enhance teacher readiness.

Students also encounter internal barriers that affect their creative thinking, such as unequal participation in group work (Almaatouq et al., 2024). Balanced group dynamics are crucial for collaboration (Johnson & Johnson, 1999), yet a lack of structured guidance often results in uneven task distribution (Sillito Walker & Bonner, 2022). Fear of making mistakes and low confidence further hinder students from expressing creative ideas (Lix et al., 2020). This aligns with Guilford's (1967) creativity theory, highlighting fluency, flexibility, originality, and elaboration as key components of divergent thinking. However, in this study, students primarily developed fluency (generating multiple responses), while flexibility and originality remained underdeveloped due to passivity in discussions and a lack of opportunities for divergent thinking. Low motivation also restricts students' ability to explore new ideas (Howard et al., 2021). While challenging and relevant tasks can enhance motivation (Ryan & Deci, 2020), the absence of complex, real-world problems in classroom activities leads to disengagement (Lin, 2021).

To improve PBL implementation, reducing administrative burdens and increasing teacher support is critical. Workload constraints can be mitigated by delegating non-teaching tasks and integrating collaborative lesson planning, allowing teachers to focus on instructional innovation. Additionally, structured professional development programs should emphasize adaptive PBL strategies, equipping teachers with techniques to accommodate diverse student needs. For students, structured group roles (e.g., leader, researcher, presenter) can balance participation and prevent passive engagement. Teachers can integrate Think-Pair-Share or the Jigsaw Method to ensure all students actively contribute. Gamification techniques, such as interactive simulations and real-world case studies, can enhance engagement and confidence in problem-solving (Adams & Du Preez, 2021). Encouraging students to document their creative process in digital portfolios can also facilitate iterative idea development, reinforcing creativity through continuous feedback and reflection.

These findings reveal a gap between theoretical frameworks and practical classroom implementation. Schools must support teachers through workload management and professional training to enhance creative learning, while students require structured collaboration, contextual learning media, and a psychologically safe environment to foster creativity. Unlike previous studies that emphasized PBL's success in fostering creativity, this study highlights that effective implementation depends on structured scaffolding and differentiated instructional strategies. Strengthening the connection between Barrows' PBL framework, Guilford's creativity model and motivation theory ensures that creative thinking skills are effectively nurtured in science education. Beyond the challenges in implementing PBL, another critical aspect influencing students' creative development is how their creative thinking skills are assessed. The effectiveness of PBL in fostering creativity is not only shaped by instructional design and classroom implementation but also by the methods used to evaluate students' creative progress. The following section explores how teachers assess creative thinking, their constraints in the process, and potential improvements to enhance assessment practices.

Assessment of Students' Creative Thinking Skills in Problem-Based Learning Settings

This study identifies key factors affecting students' creative thinking in science learning. According to OECD (2023a), creative thinking involves generating diverse and original ideas and evaluating and refining them skills essential for 21st-century education. However, implementing these skills in Indonesian classrooms faces challenges (Kartina et al., 2021; Leasa et al., 2021; Madyani et al., 2020). Teachers observe that students' creative thinking abilities vary widely, with many struggling in higher-order thinking tasks, often attributed to low academic ability. Teacher Am noted, "Some students are creative, some are not, depending on ability," while Teacher An stated, "Limited intelligence affects creativity." Similarly, Teacher Ye observed, "Students’ abilities range from high to medium." These perspectives suggest that teachers associate creativity with academic intelligence rather than viewing it as a distinct skill that can be nurtured through appropriate instructional and assessment strategies.

Creativity assessment remains limited, primarily relying on direct questioning and structured problem-solving, rarely evaluating the creative process. Due to students' academic challenges, assessments focus on summative tests rather than deeper analysis. Teacher Ye noted that higher-order thinking skills (HOTS) assessments are rarely applied. At the same time, Mrs An and Mrs Am have highlighted the lack of portfolio-based evaluations, favouring direct questioning due to students' difficulty with complex tasks. Classroom observations confirm that students struggle with experimentation, abstract reasoning, and mathematical calculations, particularly when required to summarize and explain results. While active learners display more creativity, many remain passive, reinforcing the need for improved instructional and assessment strategies to support creativity development. Data were collected before and after its implementation to evaluate the effectiveness of Problem-Based Learning (PBL) in enhancing students' creative thinking skills. Table 2 presents the distribution of students across three skill levels: low, middle, and high.

Table 2. The documentation of creative thinking skills result

Level of Creative Thinking Skills	Before Implementation PBL	After Implementation PBL
Low	68%	65%
Middle	24%	21%
High	8%	14%

As shown in Table 2, the proportion of students with high creative thinking skills increased from 8% to 14%, while those in the low category slightly decreased from 68% to 65%. Although this indicates a modest improvement, many students struggle with creative problem-solving. The decline in the middle category (24% to 21%) suggests that while some students moved to the high category, others remained stagnant or regressed. This finding aligns with research by Simanjuntak et al. (2021), which suggests that traditional instruction prioritizing memorization over exploratory learning limits students' ability to apply creativity in problem-solving contexts. From a theoretical perspective, creativity is not solely linked to intelligence but also involves cognitive flexibility and openness to new experiences (Guilford, 1967; OECD, 2022). This view aligns with constructivist learning theories, emphasizing that students actively construct knowledge by integrating new ideas with prior experiences (Piaget, 1978). However, the limited impact of PBL on lower-performing students suggests that the effectiveness of PBL depends not only on the learning approach itself but also on the way creativity is assessed and nurtured in the classroom. Three key themes emerged in this study: assessment constraints, assessment methods, and teachers’ views on students’ creative levels (see Figure 3).

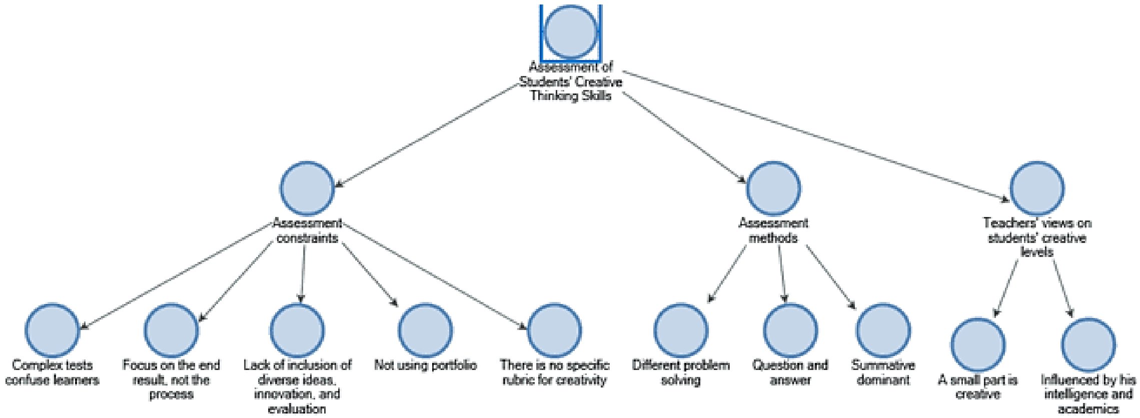

Figure 3. NVivo map results on students' creative thinking skills assessment

Findings from the NVivo Map Results on Students' Creative Thinking Skills Assessment highlight three key themes: teachers' perceptions of creativity, assessment methods, and challenges. Many teachers tend to equate creativity with academic intelligence, leading to the assumption that only a small subset of students is genuinely creative. However, before PBL, only 8% of students demonstrated high creative thinking skills, while 68% fell into the low category. After PBL implementation, the proportion of highly creative students increased to 14%, while those in the low category only slightly decreased. This suggests that while PBL contributed to fostering creativity, its overall impact remained moderate, indicating that assessment practices may support or limit students' creative development (Ramírez-Montoya et al., 2022). Teachers primarily rely on summative assessments, such as standardized tests, multiple-choice questions, and structured problem-solving tasks, to evaluate students' creative thinking skills. While these methods effectively measure knowledge retention, they fail to capture creativity's iterative, exploratory, and multidimensional nature. This contradicts formative assessment principles, emphasising active observation, feedback, and student participation in learning (Black & Wiliam, 1998). Studies have demonstrated that formative assessments such as self-reflection, peer evaluation, and project-based assessments enhance students' engagement in higher-order thinking and creativity (Moyo et al., 2022).

To better align assessment with creativity development, structured creativity rubrics can evaluate originality, flexibility, elaboration, and fluency in students' responses (Amabile, 1983; OECD, 2022). Additionally, digital portfolios can provide students with a platform to document their creative processes over time, allowing teachers to assess the final product and the iterative development of ideas (Moruzzi, 2021). Expanding project-based and formative assessments such as self-reflection activities, peer evaluations, and open-ended problem-solving tasks can offer students more significant opportunities to engage in higher-order thinking (Alt & Raichel, 2022). Professional development is also crucial for teachers to ensure they have the skills to implement creativity assessments effectively. Countries successfully incorporating process-based creativity assessments report higher student engagement and creative outcomes (Ho & Kozhevnikov, 2023). By integrating these strategies, educators can create learning environments that support creative thinking and problem-solving in science education. This study highlights the critical role of assessment in shaping students' creative thinking skills. While PBL contributed to an increase in highly creative students, the persistence of a sizeable low-category group suggests that assessment methods may be limiting creativity development. Summative assessments remain dominant, which may hinder students from fully exploring and refining their creative potential. Moving toward process-based, formative assessments such as rubrics, portfolios, and peer evaluations will be essential in aligning classroom practices with creativity theories and constructivist pedagogy.

▪ CONCLUSION

This study reveals that while problem-based learning (PBL) can potentially enhance students' creative thinking skills, its effectiveness is influenced by various challenges. Teachers face constraints such as heavy workloads, limited learning media, and difficulties in differentiating instruction, while students struggle with low motivation, passive participation, and fear of making mistakes. These obstacles hinder the full development of creativity, particularly in encouraging students to generate and refine original ideas. Without structured support, PBL alone cannot maximize students' creative potential. To improve PBL implementation, a more structured approach is needed, which integrates open-ended tasks, scaffolding techniques, and formative assessment methods that capture the creative process beyond summative evaluations. Strengthening teacher training and resource allocation will help educators facilitate creativity-focused learning more effectively. Additionally, structured collaboration strategies should be applied to ensure active participation and equitable group work. By addressing these challenges, PBL can better support the development of creative thinking skills and prepare students for complex problem-solving in real-world contexts.

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