

Initiatives to Enhance Students' Creative Thinking Abilities in Chemistry Education: A Systematic Literature Review

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ABSTRACT

Creative thinking is an important skill for the 21st century, especially in chemistry education, where students need to approach tough problems in new ways. This review looks at different learning models that can help improve creative thinking in chemistry. We focused on articles from 2015 to 2024, narrowing it down to eight key studies for a closer look. The results show that methods like Project Based Learning and Problem Based Learning, particularly when combined with STEAM elements, greatly aid in building creative thinking skills. These approaches encourage essential qualities like fluency, flexibility, originality, and elaboration. Moreover, using scaffolding techniques and incorporating local cultural elements into lessons can boost learning outcomes. However, there are still some challenges to face, like the limited use of these methods in traditional classrooms and the need for more teacher training in innovative teaching styles. This review highlights the value of using varied, student-focused learning models to nurture creativity, providing useful guidance for educators and researchers in the field of chemistry education

INTRODUCTION

Creative thinking is acknowledged as a skill essential for the 21st century. Creative thinking refers to the capacity of the cognitive process to produce novel and distinctive ideas for problem-solving (Nahar, 2023). Essentially, learning is not merely about memorizing and gathering information but is a communicative process involving the transmission of messages between the stimulus and the receiver (Rahadiyani et al., 2023). Chemistry is inherently tied to experimental activities, as it combines products, processes, and attitudes essential for discovery and problem-solving (Sumarti, Aris & Aini, 2018). Chemical concepts are deeply intertwined with all aspects of human life. However, current teaching methods often fall short in helping students fully grasp these concepts across different educational levels (Ghani et al., 2023). One of the goals of education is to transform students into creative humans. Creative people are original in their thinking, develop new ideas, and elaborate on a concept (Rusmansyah et al., 2024). In the context of education, particularly in disciplines such as chemistry, the attitudes of learners represent a vital component that must be considered. The rejection of negative attitudes is critical, as it can significantly influence the outcomes of the learning experience (Astalini et al., 2019).

Creative thinking is a mental process for using various strategies to solve problems, analyze various points of view, adapt ideas, create new solutions, and evaluate ideas in problem-solving (DeHaan, 2009) (Kaufman & Sternberg, 2007). This skill can train students to develop ideas and arguments to be open and responsive to different perspectives (Anwar, et al. 2012) For example, creative thinking skills in chemistry lessons can open new perspectives for students to answer problems (Hadzigeorgiou, et al., 2012). Moreover, creative thinking skills are essential across various domains, including but not limited to science, technology, medicine, and the arts. These skills emerge from the fundamental cognitive processes that allow for the synthesis of disparate concepts, leading to the formulation of novel ideas derived from existing knowledge (Lynch et al., 2019).

It is crucial to understand that creative thinking is not a natural talent but a skill developed through education, experience, and practice (Redhana, 2019). Indicators of creative thinking skills can be observed in learners' competencies to tackle complex problems, discern relationships that may not be immediately apparent, and construct appropriate conceptual models for the explanation of various phenomena (Lawless et al., 2018). Thus, understanding and fostering these skills is paramount for successful engagement in contemporary educational frameworks.

Contextual and student-centered learning approaches can enhance the development of creative thinking abilities (Suradika et al., 2023). This type of creativity aids societal progress through inventions and discoveries while also changing how people interact with the world, one another, and themselves. These transformations encourage increased adaptability and receptiveness to change (Glaveanu et al., 2020). The significance of creative thinking has been amplified due to the influences of rapid globalization, heightened competition, and technological advancements (Alencar et al., 2016).

In contemporary contexts, a decline in motivation, particularly concerning secondary education students, has been observed, which impedes engagement in learning, especially within scientific disciplines (Rivas, P. G., 2017). In response to the demands of the 21st century, educational policies have been revised to incorporate teaching frameworks that prioritize Higher Order Thinking Skills (HOTS), specifically the 4C framework, encompassing Creative, Collaborative, Critical, and Collaborative skills (Rais et al., 2021). In this context, creative thinking is essential for developing innovative learners who can recognize solutions to the progressively complex challenges they will face in the future.

Additionally, as expressed by Gilakjani (2011), creative thinking is defined as inventive thinking applied in problem-solving approaches. Some things that cause in chemistry learning, students' creative thinking skills are still not well developed. First, the teacher does not know the right way to increase students' creativity in the learning process in the classroom. Second, this ability is too difficult if applied to students who have limited knowledge and thinking skills. Third, schools lack access to students to develop their ability to think independently. Fourth, the learning process in schools emphasizes unproductive thinking, focuses on memorization and looks for one correct answer to the questions given. This will certainly result in the inhibition of students' creativity (wijayati et al., 2019).

Someone who has a high level of creative thinking, their learning outcomes will be satisfying. This is because with the ability to think creatively, people will have a fast way of thinking, be superior in thinking and find solutions to the problems they encounter (wardani et al., 2021). Creative thinking is one type of thinking that directs gained new insight, new approaches, new perspectives, or new ways of understanding things. Creative thinking occurs when triggered by tasks or challenging problems. (Ananda et al., 2016). Learning activities foster students' creativity in solving problems if students are trained to develop original ideas to decide problem-solving in certain situations (Sumrani et al., 2022). To understand how well students can think creatively, we need to measure their skills. This helps us see where they stand and encourages them to improve. According to Torrance, creative thinking includes being fluent, flexible, original, and detailed (Friedel & Rudd, 2006).

LITERATURE REVIEW

When students think creatively, they can look at the world in different ways, allowing them to find new answers to real-world challenges (Kose & Arslan, 2017). Right now, students in Indonesia are not fully developing their creative thinking abilities, which are still considered low. According to the 2018 PISA results, Indonesian students placed 74th out of 79 countries, scoring 396 out of a possible 500 points (Dewi & Mashami, 2019; Lestari & Ilhami, 2022). This evidently demonstrates that students in Indonesia have deficiencies in their creative thinking abilities. From the Above, it is evident that students' creative thinking abilities in chemistry still have potential for improvement. For this reason, the researcher is conducting a comprehensive literature review to collect data on instructional models that can enhance students' creative thinking

abilities, as well as the educational strategies that can facilitate this progress in chemistry.

METHODOLOGY

The approach employed in that research is a systematic literature review. A systematic literature review is a method that adheres to established guidelines for identifying and synthesizing pertinent research articles (Xiao & Watson, 2019). A systematic literature review consists of three phases: planning, Conducting, and reporting.

1. Planning Stage

During the planning phase, the researcher identifies the research subject, specifically the initiatives to enhance students' creative thinking abilities. At that phase, the criteria for the articles that must be applied are also being established. These standards are outlined in that Table 1.

Table 1. Article Criteria

Criteria	Description
Inclusion	<ol style="list-style-type: none">1. The article discusses the learning model applied to develop Creative thinking skills in chemistry learning.2. The articles used are those published between 2015 and 2024.3. Scopus and Sinta-indexed articles (minimum Sinta 3).
Exclusion	<ol style="list-style-type: none">1. Articles that do not discuss learning models that are applied to develop Creative thinking skills in chemistry learning.2. Literature review articles are not included.

2. Conducting Stage

To begin this process, we gathered articles that fit specific criteria. We searched through databases like ERIC and Google Scholar using the phrase "creative thinking skills in chemistry learning." From this search, we found 201 articles on ERIC and 103 on Google Scholar. Next, we went through the abstracts of these articles. If an abstract related to our research topic, we read the full article. After careful review, we identified 8 articles suitable for our systematic literature review, which are listed in Table 2. The next step involves extracting data and combining the important information from these selected articles

3. Reporting Stage

The Last phase in which there is writing down the results of that literature review.

Table 2. The Article Which are Used in that Systematic Literature Review

No.	Author	Article titles	Journals
1	Wijayati et al., 2019	Improving Student Creative Thinking Skills Through Project Based Learning	UNNES International Conference on Research Innovation and Commercialization 2018 Volume 2019
2	Ghani et al., 2023	Implementation of Chemo-entrepreneurship through Project-based Learning to Determine the Level of Students' Soft Skills and Learning Motivation	Journal of science learning
3	Rusmansyah et al., 2024	The development of steam-based LKPD - PjBL acid-base solution material to improve creative thinking ability	Jurnal Inovasi Pembelajaran
4	Sumarni et al., 2022	STEM-PBL-Local Culture: Can It Improve Prospective Teachers' Problem-solving and Creative Thinking Skills?	Journal of innovation and cultural research
5	Ananda et al., 2016	DEVELOPMENT STUDENT WORKSHEET ORIENTED PROBLEM BASED LEARNING TO TRAIN CREATIVE THINKING SKILLS IN CHEMICAL EQUILIBRIUM MATTER .	Unesa Journal of Chemistry Education
6	Ernawati et al., 2022	Analysis of problem based learning in the scaffolding design: Students' creative-thinking skills	Cypriot Journal of Educational Sciences
7	Nuswowati et al., 2015	DEVELOPING CREATIVE THINKING SKILLS AND CREATIVE ATTITUDE THROUGH PROBLEM BASED GREEN VISION CHEMISTRY ENVIRONMENT LEARNING	Indonesian Journal of Science Education
8	Perdana et al., 2020	The Effectiveness of Inquiry Social Complexity to Improving Critical and Creative Thinking Skills of Senior High School Students	International Journal of Instruction

Table 3. The Learning Models and the Syntex Which Are Used

Learning Model	Learning syntax	Authors
Pjbl	Determining essential questions Project planning Project scheduling Monitoring and evaluation Finalizing the project	Wijayati et al., 2019
CEP- Pjbl	research preparation, research implementation, data analysis, conclusion	Ghani et al., 2023
STEAM- Pjbl	Problem identification Initiate investigation Plan and design solution Execute the project Reflection and Presentation.	Rusmansyah et al., 2024
STEAM PBL	Presenting a problem. Collaborativeproblem-solving. Integration of STEM and local culture. Assessment.	Sumarni et al.,2022
PBL	Problem Presentation. Guided Inquiry. Collaboration Solution Development and Evaluation	Ananda et al., 2016
PBL model with scaffolding	Problem orientation Group discussion Classical discussion Scaffolding stage I Elaboration Classical discussion of elaboration Scaffolding stage II	Ernawati et al., 2022
PBL	Problem Presentation. Guided Inquiry. Collaboration Solution Development and Evaluation	Nuswowati et al.,2015
ISC	observation team, (2)reconstruction, (3)socialization, (4)verification, (5)applied communication.	Perdana et al., 2020

Table 4. Learning Models to Develop Students' Creative thinking Abilities

Model Type	Integrated Model	Percentage
Problem based learning	PBL (2)	50%
	STEAM -PBL(1)	
	PBL With Scaffolding(1)	
Project Based Learning	PJBL (1)	30%
	STEAM PJBL (1)	
	CEP-PJBL (1)	
Inquiry Based Learning	INQUIRY SOCIO COMPLEXITY MODEL(1)	20%

RESULTS AND DISCUSSION

Creative thinking is essential for doing well in our fast-paced, information-filled world. This is especially the case in chemistry education, where students need to grasp complicated scientific ideas and figure out how to use them in creative ways to tackle real-life challenges. To promote creative thinking, educators must implement teaching methods that involve students in the learning experience. An analysis of eight scholarly studies indicates that different innovative learning models have successfully improved creative thinking abilities. Below, we discuss the important findings from these models:

1. Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is regarded as an effective method to cultivate students' deep understanding and enhance their creative and critical thinking abilities. It focuses on providing students with real-world challenges that require innovative and collaborative solutions. This method promotes students to consider unconventional ideas, assess situations thoroughly, and work well with their peers.

Sumarni and associates (2022) explored the integration of PBL with STEM concepts and local cultural elements in educator training initiatives. Their results indicated moderate advancements in both creative thinking and problem-solving abilities, backed by a significant correlation coefficient of 0.657. This indicates that these skills are interconnected, with each one aiding the development of the others. Participating in problem-solving activities increases students' curiosity about science and enhances their understanding of cause and effect, thereby promoting their creativity. Simultaneously, engaging in creative tasks enhances their problem-solving abilities, demonstrating how these skills interact and aid one another in the learning process. This research highlights the significance of implementing active learning techniques to develop not only technical skills but also the critical thinking and creativity essential for efficient problem-solving in education.

The use of PBL worksheets has also been shown to enhance students' creative thinking abilities in chemistry, particularly in the context of chemical equilibrium. Ananda et al. (2016) developed a Problem-Based Learning (PBL)-oriented student worksheet to enhance creative thinking skills specifically in the context of chemical equilibrium. The study used a 4-D development model and

targeted high school students. The worksheets were evaluated for feasibility based on content relevance, presentation quality, and graphical design, all of which were rated as very good to excellent (above 81%) by validation results. The findings suggested that these worksheets effectively facilitated a deeper engagement with the material and promoted creative problem-solving. They included contextual problems that encouraged students to actively find solutions and understand the real-world applications of chemical equilibrium, thus honing their analytical and creative thinking skills.

Another important aspect of PBL is the integration of scaffolding techniques. According to (Ernawati et al., 2022; Sumarni et al., 2022), scaffolding helps guide students through the learning process by breaking down complex problems into manageable steps. In biochemistry courses, scaffolding in PBL not only improved creative thinking skills but also increased student enthusiasm and participation. This approach encourages students to take ownership of their learning by actively engaging with real-world problems and collaborating with peers to find solutions. The study reveals distinct differences in creative thinking skills among students in classes A, B, and C when using the Problem-Based Learning (PBL) model integrated with scaffolding in biochemistry courses. Students in Class A, who engaged with the Scaffolding-integrated PBL learning model, demonstrated the highest level of creative thinking skills.

These students benefited from a more supportive learning environment that encouraged collaboration, active problem-solving, and real-world application of concepts. This approach, which emphasizes hands-on learning and teamwork, appears to significantly enhance students' creative thinking abilities. Class B, which used the traditional PBL model, showed moderate improvement in creative thinking skills, suggesting that while the model supports student engagement and inquiry-based learning, the integration of scaffolding provided additional benefits. Class C, which followed conventional learning methods, had the lowest scores, highlighting the importance of more interactive and structured learning experiences to foster creative thinking.

ANOVA tests confirmed these differences, indicating a statistically significant variance in creative thinking skills across the classes with a significance level of 0.000. Students in Class A, who benefitted from the scaffolding-integrated PBL learning, were found to have higher creative thinking skills compared to their peers in Classes B and C. This can be attributed to the interactive and supportive nature of the learning environment, which provides the motivation and guidance needed to tackle complex problems creatively. The scaffolding integrated PBL model not only facilitates better engagement with biochemistry concepts but also nurtures a more creative and critical mindset among students. By dealing with real-world problems in a structured manner, students develop both their problem-solving skills and their ability to think outside the box.

In environmental chemistry, PBL has proven particularly effective when paired with green chemistry principles. Nuswowati et al. (2015) examined the impact of Problem-Based Learning (PBL) with a Green Chemistry vision on enhancing creative thinking skills and attitudes among students. The results showed that the experimental class, which used the PBL approach integrated with

a Green Chemistry vision, significantly improved creative thinking skills more than the control class. The N-gain score of 0.71 for the experimental class indicated a high category of improvement, while the control class scored 0.40, indicating a lower level of improvement.

Alongside cognitive abilities, the execution of the Green Chemistry vision also positively impacted students' inventive approaches to addressing environmental issues. In the experimental class, students exhibited moderate creative attitudes marked by a sense of responsibility, perseverance, discipline, and a collaborative spirit. These positive characteristics were less apparent in the control class, which employed a more traditional method of teaching chemistry. The research indicates that PBL incorporating Green Chemistry principles effectively promotes cognitive growth as well as social and ethical perspectives vital for tackling environmental issues. This method encourages students to actively think about environmental issues, fostering critical thinking and promoting a more sustainable mindset towards the environment. Future studies should examine these effects using various assessment methods, such as observations and portfolios, to achieve a broader understanding of students' creative attitudes and their progression over time.

2. Project-Based Learning (PjBL)

Project-Based Learning (PjBL) takes a different advanced route by working with the long-term, hands-on projects. These projects encourage students to use information from what they've learned and create real results from it. This method is especially helpful in chemistry classes, where getting hands-on experience is important for effective learning.

Wijayati et al. (2019) demonstrated how PjBL can enhance students' creative thinking skills by engaging them in the creation of basic pyrolysis and distillation equipment. The study employed a Project-Based Learning (PjBL) approach, concentrating on a hands-on project to develop essential pyrolysis and distillation apparatus. The research was conducted over three phases, focusing on improving the creative thinking skills of chemistry students. During every phase, students participated in addressing real-life challenges, designing, and building the necessary tools. The findings indicated a notable improvement in creative thinking abilities, particularly in fluency and elaboration, with students reaching a "creative" level on average for all metrics by the conclusion of the third cycle. This suggests that PjBL successfully enhances student involvement and creativity in studying chemistry. The conclusion indicates that incorporating PjBL into chemistry education can greatly improve students' creative thinking skills through interactive, problem-solving activities.

Similarly, the Contextual and Experiential Pedagogy (CEP) strategy, when combined with PjBL, has been shown to improve not only creative thinking but also learning motivation and soft skills. Ghani et al. (2023) applied the Chemo-entrepreneurship approach through a Project-based Learning (PjBL) model to investigate its impact on student learning motivation and soft skills. The research procedure involved designing and implementing PjBL tasks that integrated entrepreneurial concepts with chemistry education. This was done to assess how these tasks influenced student motivation and the development of soft skills such

as teamwork, problem-solving, and communication. The study involved both experimental and control groups, with the experimental group experiencing PjBL tasks that required them to work on real-world problems and develop innovative solutions. The analysis showed significant differences in learning motivation and soft skills between the groups, indicating that the PjBL model was effective in enhancing these aspects compared to traditional learning methods. The results suggest a positive impact on student engagement and skills development through the use of the CEP learning strategy in a PjBL framework.

The integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) principles into PjBL further enhances its effectiveness. Rusmansyah et al. (2024) evaluated STEAM-oriented worksheets designed for teaching acid-base solutions and found that they significantly improved students' creative thinking abilities. These materials achieved a validation score of 95.5% for content and presentation, and their efficacy was supported by an N-gain of 76%. The study underscores the importance of well-designed instructional resources in maximizing the impact of PjBL.

3. Inquiry and Socio-Complexity Model (ISC)

The Inquiry and Socio-Complexity (ISC) model represents a novel strategy that merges inquiry-driven education with the investigation of intricate social problems. This model promotes critical and creative thinking in students regarding real-world issues, rendering it especially pertinent in our fast-evolving and interconnected world. Perdana et al. (2020) explored this topic by assessing the effectiveness of the Inquiry Social Complexity (ISC) learning framework aimed at improving critical and creative thinking skills among senior high school students in Indonesia. The method utilized for the study was experimental, incorporating a pre-test and post-test group design. The research sample included 32 students using the ISC model and 30 students applying Discovery Learning in the acid-base topic. The data analysis was conducted using the ANCOVA test, resulting in an $F = 79.381$ at a significance level of 0.000 ($p < 0.05$), which suggests there were significant differences between using the ISC model and applying Discovery Education.

The results of the pre-test and post-test showed a difference of 39.66% for the experimental group and 24.83% for the control group. It can be deduced that the ISC learning model significantly improves students' educational experience, as well as their analytical and creative thinking skills. By combining inquiry-based learning with socio-complexity, the ISC model enables students to investigate open-ended questions and work together to address complex issues. This method corresponds effectively with the requirements of 21st-century education, which prioritizes creativity, teamwork, and problem-solving skills.

CONCLUSIONS AND RECOMMENDATIONS

This review highlights significant efforts to foster creative thinking skills in chemistry education through innovative-learning models. Project Based Learning and Problem Based Learning, along with their variations like STEAM-PBL and CEP-PjBL, have proven effective in enhancing students' ability to think creatively. These models encourage active participation, collaboration, and contextual problem-solving, making learning more engaging and impactful. The use of scaffolding in PBL further refines students' critical and creative thinking processes, while the integration of local culture and real-world applications broadens their perspective. However, the findings also underscore challenges, including the need for comprehensive teacher training and the integration of these models into traditional curricula. Addressing these issues could further elevate the creative capacities of students, especially in chemistry education.

Implication

The examined studies emphasize the transformative power of active learning models in chemistry education. These models change the emphasis from passive knowledge gathering to active involvement, allowing students to interact thoroughly with the content and take charge of their own education. Conventional teaching approaches, which frequently focus on memorization, do not stimulate students or foster their creative abilities. Conversely, frameworks such as PBL, PjBL, and ISC foster dynamic learning settings that promote exploration, teamwork, and creativity.

Interdisciplinary methods also improve the efficacy of these models. For example, incorporating STEM, STEAM, and green chemistry concepts enhances the relevance and practicality of chemistry classes. These frameworks assist students in recognizing the links between chemistry and real-world issues, inspiring them to think innovatively and make valuable contributions to global challenges. An additional important element is the function of instructional materials. As shown by Rusmansyah (2024) quality resources are crucial for effectively implementing active learning models. Teachers ought to emphasize creating well-structured worksheets, project instructions, and evaluation tools to enhance student involvement and educational results.

Challenges and Considerations

Although the advantages of active learning models are clear, their execution comes with difficulties. A major challenge is the requirement for comprehensive teacher training. Numerous educators might not possess the skills or confidence necessary to implement innovative teaching techniques, especially those that demand extensive planning and facilitation. Offering professional development opportunities and continuous support is essential for tackling this issue. Another hurdle is the possible resistance from students who are used to conventional teaching methods. Active learning approaches require students to engage more and take on greater responsibility, which can be daunting or stressful for certain individuals. To address this, teachers ought to slowly implement these techniques and offer clear instructions and assistance.

Future Research Directions

Although the studies mentioned provide useful insights, further investigation is necessary to examine the lasting effects of active learning models on creativity and critical thinking abilities. Longitudinal studies might offer a more thorough insight into the development of these skills over time and their impact on students' academic and career achievements. Moreover, subsequent studies ought to investigate how adaptable these models are in various cultural and educational settings. The effectiveness of a specific teaching model can fluctuate based on factors like classroom size, student demographics, and accessible resources. Investigating these differences may result in more accommodating and adaptable teaching methods. The function of technology in facilitating active learning models is another aspect deserving exploration. Digital resources like virtual laboratories, online collaboration tools, and interactive simulations can significantly improve the application of PBL, PjBL, and ISC models. These resources may enhance the accessibility and engagement of active learning, especially in remote or resource-constrained environments.

FURTHER STUDY

This study still has limitations so that further research is needed on the topic of Initiatives to Enhance Students' Creative Thinking Abilities in Chemistry Education: A Systematic Literature Review to perfect this study and increase insight for readers and writers.

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