JPII 14 (1) (2025) 70-82

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

CASE-BASED LEARNING FOR CREATIVE THINKING SKILLS ON THE IDEAL GAS LAW: APPLICATION OF THE UNDERSTANDING BY DESIGN FRAMEWORK

T. Nurita[1,2], L. Yuliati*[2], S. K. Handayanto[2], A. Hidayat[2], P. Saleah[3]

[1]Department of Science Education, Universitas Negeri Surabaya, Surabaya, Indonesia
[2]Department of Physics Education, Universitas Negeri Malang, Malang, Indonesia
[3]Department of General Science Education, Faculty of Science Technology and Agricultural, Yala Rajabhat University, Yala, Thailand

DOI: 10.15294/jpii.v14i1.16938

Accepted: February 11th, 2025. Approved: March 29th, 2025. Published: March 30th 2025

ABSTRACT

The development of the 21st century and education are closely related in equipping students with relevant skills to adapt and succeed in an ever-changing environment. This development demands a more interactive, collaborative, and student-centered learning method. Case-based learning (CBL) is designed to facilitate students' thinking critically and creatively in solving problems and working in teams so that they can face real-world problems that are integrated into learning. The Understanding by Design (UbD) framework facilitates cases in learning designed to suit students' interests and needs, enhancing creative thinking skills when integrated with CBL. This study uses a mixed or explanatory method and involves 115 students. Quantitative data was obtained from creative thinking skills tests using pre-test and post-test, which showed differences between the pre-test and post-test and a correlation between creative thinking skills indicators (fluency, flexibility, originality, and elaboration). Qualitative data from classroom observations showed that students performed the activities well and were supported by interview data, which revealed that students were actively involved in learning, although some students could not relate concepts to problems. These findings support the idea that CBL with the UBD framework helps students understand the ideal gas law and improves creative thinking skills. This study suggests that students can develop better problem-solving skills because the UbD framework facilitates a structured and meaningful learning experience for students.

Keywords: creative thinking skills; understanding by design; ideal gas law; case-based learning

INTRODUCTION

In the 21st century, it is expected that everyone related to the needs and complexities of life in modern society will be expected to follow the Sustainable Development Goals (SDG), particularly Goal 4: Education. Creative thinking skills in science and technology are the main focus of the education curriculum. Indonesian students' low creative thinking skills pose a significant challenge, especially considering the Global Innovation Index (GII). The GII emphasizes the importance of innovation and creativity in driving economic development (WIPO, 2024). Despite Indonesia's growing global recognition, students perform poorly in assessments assessing creative problem-solving and innovation. Traditional educational methods that emphasize rote memorization fail to cultivate creative competencies. Low critical thinking and creativity scores hinder Indonesia's potential to compete globally, as indicated in the GII (WIPO, 2024). Engaging pedagogies like Case-Based Learning enhances critical thinking and creativity by facilitating collaborative problem-solving (Lavi & Marti, 2023). However, conventional teaching paradigms must shift towards dy-

***Correspondence Address**
E-mail: lia.yuliati.fmipa@um.ac.id

namic, student-centered approaches prioritizing innovation and creativity. Addressing this issue is imperative for enhancing Indonesia's innovation capacity and competitiveness in the global economy.

Creative thinking skills create something new, produce different ideas or notions, create solutions to solve problems and create new projects. Creativity also comes from thinking to solve problems. The creative thinking process combines logical and divergent thinking, flexibility, and originality and produces various ideas, solutions, and answers from various perspectives to overcome various problems (Runco & Garrett, 2012). Therefore, several studies have used learning strategies to improve students' creative thinking skills (Alani et al., 2022; Çetinkaya, 2024). Creative thinking skills are important in education and help individuals adapt to change and overcome new challenges (Oo et al., 2024).

Case-based learning (CBL) is one type of learning that can build creative thinking skills. It combines the application of theory in everyday life. It is an active learning process that makes students think critically and creatively when solving complex problems. Before this study, several other studies showed that CBL could improve students' conceptual understanding, analytical skills, and learning motivation (Sudibyo et al., 2016; Raza, 2020; Raza, 2020; Burgess et al., 2021). With case-based learning, students can improve their thinking skills through experience in solving problems and applying them in everyday life. CBL fosters creative thinking in abstract physics by connecting theoretical principles to practical applications. CBL engages students in problem-solving through complex, real-world scenarios, enhancing their ability to apply physics concepts (Rudzińska et al., 2024; Wang et al., 2024). CBL allows students to explore diverse scenarios, requiring critical thinking about underlying physics principles like motion, energy, and forces. Research shows that CBL strengthens abstract material comprehension and encourages innovative problem-solving approaches, deepening cognitive engagement. Group discussions and collaborations expose students to diverse perspectives and strategies, cultivating creativity. This dynamic learning environment enhances knowledge retention and empowers students to connect physics to personal experiences, elevating academic and practical proficiency. CBL is a pivotal pedagogical strategy in scientific education, especially for abstract disciplines like physics.

Although CBL has successfully improved conceptual understanding in several studies, it is still unclear how it influences creative thinking skills in ideal gas law (Zhao et al., 2020; Angel et al., 2021; McNiven et al., 2023). To overcome this gap, CBL must be designed based on the Understanding by Design (UbD) framework to build students' creative thinking skills in solving problems, especially in the ideal gas law. With the integration of CBL and UbD, learning can be more structured to focus on understanding, application, and reflection in creative thinking. This integration is expected to improve students' thinking skills in applying the concept of ideal gas law in everyday life. An important part of this learning is creating a learning design to achieve learning objectives, especially in building creative thinking skills (Angelo et al., 2019; Vani et al., 2022). Applying the UbD framework to design learning aims to provide an overview of learning and ensure students gain understanding (Wiggins & McTighe, 2011).

The integration between CBL and UbD can strengthen the final learning outcomes to achieve learning objectives, overcome individual differences, help create a pleasant learning atmosphere for students, and contribute to the learning process (Wiggins & McTighe, 2011; Lumbreras & Rupley, 2020). Applying CBL with the UbD framework aims to provide new insights into how such learning is applied to improve creative thinking skills in ideal gas law. With this application, students are expected to be active in learning by exploring various solutions to solve problems and equipping students with thinking skills in applying knowledge to everyday life. The results of this study are also expected to contribute to science education, especially in improving students' creative thinking skills.

Learning that involves group discussions brings up different ideas and perspectives, thus broadening students' understanding and increasing creativity in solving problems (Li & Tu, 2024). Group discussions also encourage students to be more open and determine alternative solutions to solving problems (Bharathi & Pande, 2024). In the theory of ideal gas law, students not only learn theory but are also required to think creatively, such as putting forward ideas and analyzing the relationship between pressure, volume, and temperature in everyday life cases. With interaction in group discussions, students can develop communication in solving problems (Maggiore et al., 2024). The Understanding by Design (UbD) framework, developed by Grant Wiggins and Jay McTighe, provides a structured approach to curriculum development. It emphasizes a backward design process, starting with desired learning outcomes and assessments before planning activities and resources (Wiggins & McTighe, 2011). This approach ensures coherent and focused curricula aligned with educational objectives. UbD comprises three stages: identifying desired results, determining acceptable evidence of learning, and planning learning experiences and instruction. This structured methodology prioritizes enduring understandings and avoids content overload by focusing on key ideas. Teachers collaborate with students, fostering an interactive learning environment where students become co-investigators of their knowledge. UbD is a valuable tool for shaping effective lesson plans, ensuring student-centered teaching for long-term knowledge and skill retention (Meyer et al., 2024). This study focuses on the ideal gas law to explore students' ability to see the application of this concept from a practical or socially relevant perspective. Many studies have neglected elaboration as an indicator of creative thinking. Developing elaboration skills through learning the ideal gas law helps students creatively connect various physical variables (ErenŞişman et al., 2020).

Implementing structured CBL and UbD also provides evaluation in the form of formative assessment. With formative assessment during the learning process, students can receive constructive feedback and identify what needs to be improved in developing creative thinking skills (Tirado et al., 2024). This feedback is focused on the result and the students' thinking process so that students can be more reflective in improving their creative skills. Teachers can consistently monitor students' creative thinking skills development by conducting formative assessments for the desired results (Steen et al., 2023). Therefore, combining CBL and UbD in learning can positively impact students' creative thinking skills development, thereby improving the quality of education in Indonesia. Based on the background above, the formulation of the problem is How is the effectiveness of the Case-Based Learning (CBL) model in improving students' creative thinking skills on the Ideal Gas Law material? and the aim is to describe students' creative thinking skills through the application of Case-Based Learning based on Understanding by Design.

METHODS

This study uses a mixed or explanatory method. Explanatory combines quantitative and qualitative data (Creswell & Plano, 2018). Quantitative data were collected and analyzed in the first stage, and the results were identified. Qualitative data were collected and analyzed in the second stage. The results were then interpreted to explore the application of case-based learning in improving students' creative thinking skills on the ideal gas law. This study involved 115 students in the same semester. The subjects were randomly selected from the student population at one of the universities in Surabaya to represent the student group in this study (Patton, 2014).

This design development framework uses the Understanding by Design integrated with Case Based-Learning. The design framework is presented in Figure 1.

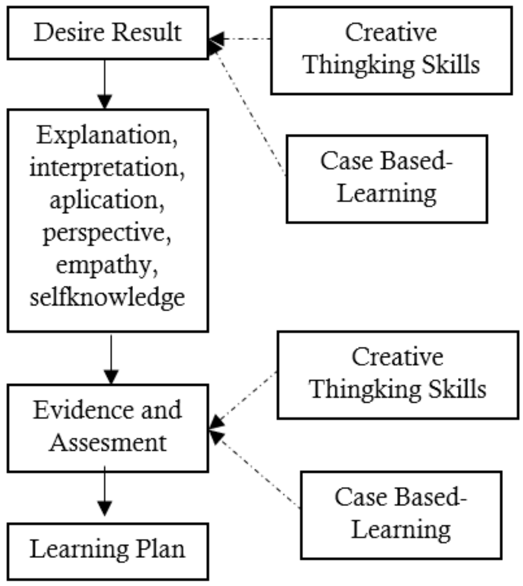

Figure 1. Understanding by Design framework integrated with Case Based-Learning

The process begins by setting the desired outcome, namely the learning objectives to improve creative thinking skills. To achieve this goal, explanations, interpretations, applications, perspectives, empathy, and self-knowledge are needed to help students understand the material thoroughly and in various contexts. Creative thinking skills and case-based learning support this process. Furthermore, evaluation and assessment are carried out to measure students' understanding of the material being studied. The results of this evaluation are used to prepare a learning plan that will improve or enhance learning strategies to be more effective.

The research instrument focuses on developing students' creative thinking skills, including creative thinking skills tests designed to develop students' creative thinking skills based on the following indicators: fluency, flexibility, originality, and elaboration (Runco et al., 2010) and UbD understanding indicators: explanation, interpretation, application, perspective, empathy, and self-knowledge (Wiggins & McTighe, 2011) (Table 1). This test is an essay to assess how well students can develop creative thinking skills and apply the ideal gas law in a case about the ideal gas law that includes previous indicators. Classroom observations and interviews were also conducted to provide qualitative data during learning and identify whether case-based learning can help achieve learning objectives. Student activities during learning were observed by providing cases of the ideal gas law in everyday life. Several students were interviewed to discover their experiences during CBL and how CBL affected their understanding.

Table 1. Indicators Creative Thinking Skills with UbD by Wiggins and McTighe

UbD Understanding Aspects	Creative Thinking Skills Indicators
Explanation	Explaining concepts accurately (fluency)
Interpretation	Interpreting information or data in detail (elaboration)
Application	Applying concepts in various cases (flexibility)
Perspective	Providing different perspectives in different cases (flexibility)
Empathy	Empathizing with the concept (elaboration)
Self-Knowledge	Reflecting a unique and original understanding of concepts (originality)

The Understanding by Design (UbD) framework emphasizes creative thinking skills indicators like fluency, elaboration, flexibility, and originality. Accurately explaining concepts enhances fluency, enabling clear articulation. Barnes et al. (2024) highlight empathic understanding in industrial design, supporting effective communication and idea expression. Interpreting information details fosters elaboration, as Fuentes et al. (2022) distinguish between cognitive and emotional empathy in adolescents, emphasizing the importance of in-depth comprehension.

Flexibility in applying concepts across contexts aligns with adaptability in communication. However, the provided citation supports deceit elicitation rather than communication flexibility. Therefore, it is removed for accuracy. Empathizing with concepts enhances elaboration, promoting a deep and nuanced understanding. Davison (2017) argues for historical empathy in fostering civic identity and diverse perspectives. Reflecting a unique and original understanding is crucial for originality in creative endeavors, as McKinnon asserts that empathy in nursing requires creativity and emotional engagement to solve complex problems (McKinnon, 2018). These studies converge on the essential role of these indicators in cultivating robust creative thinking skills aligned with UbD principles, fostering a rich learning and innovation environment.

The research procedure was conducted in several stages. In the preparation stage, cases relevant to the ideal gas law were developed, creative thinking skills tests (pre-test and post-test) were prepared based on indicators of fluency, flexibility, originality, and elaboration with aspects of understanding from UbD, and observation and interview guides were prepared. The second stage was implementation, which began with distributing pre-tests and then continued with implementing CBL and UbD, as well as classroom observation to observe teacher and student activities. The implementation stages are described in Table 2.

Table 2. Implementation Stage

Stage	Implementation
1	Distributing the pre-test to all participants
2	Implementation learning; Students discuss and work in groups to analyze and solve cases related to the ideal gas law
3	Collecting data through classroom observation
4	Distributing post-tests to measure changes in students' creative thinking skills
5	Collecting data through interviews after learning

This study uses quantitative and qualitative data analyses. Both are conducted to provide a more comprehensive understanding of the effectiveness of case-based learning. Pre-test and post-test scores are analyzed quantitatively. Data are analyzed using descriptive and inferential statistical methods to determine significant differences in CBL and UbD integration results. Correlation tests are also conducted to determine indicators of creative thinking skills (fluency, flexibility, originality, and elaboration). The results of this analysis describe the effectiveness of applying CBL and UbD in developing students' creative skills. Qualitative analysis uses a thematic approach to determine patterns related to creative thinking skills and identify insights related to applying CBL and UbD in improving creative thinking skills (Braun & Clarke, 2019). This qualitative data is also used to describe students' learning experiences and perspectives in the learning process.

RESULTS AND DISCUSSION

Table 3 shows the results of descriptive and inferential statistical analysis of quantitative data using post-test scores. Pre-test data were not analyzed in descriptive statistical analysis, and this study only focused on the results of the post-test to see the achievements and measure students' creative thinking skills after implementing Case-Based Learning (CBL) based on Understanding by Design (UbD) on the Ideal Gas Law material. The results obtained were measured using a scale of 100 to facilitate calculations.

Table 3. Descriptive Statistical Analysis

	Fluency	Flexibility	Originality	Elaboration
Valid	115	115	115	115
Missing	0	0	0	0
Median	78.57	75.00	75.00	67.86
Mean	80.44	75.99	73.32	67.39
Std. Deviation	6.83	6.70	7.62	7.14
Coefficient of variation	0.085	0.088	0.104	0.110
Variance	46.62	44.87	58.40	54.94
Range	32.14	25.00	35.71	32.14
Minimum	67.86	64.29	53.57	53.57
Maximum	100,00	86.29	89.29	85.71

Based on Table 3, the fluency indicator has the highest mean (80.44), indicating that students, on average, have higher fluency compared to flexibility (75.99), originality (73.32), and elaboration (67,39). The fluency indicator has the highest median (78.57), while the elaboration indicator has the lowest median (67.86). The originality indicator (7.14) has the highest standard deviation, which shows the largest variation in originality-related responses. The low coefficient of variation value (between 0.085 and 0.110) indicates that the data is relatively homogeneous. These results indicate that students tend to be quite consistent for each indicator. Fluency has the highest range (32.14 to 100), while flexibility has the lowest range (25.00 to 86.29).

Furthermore, a normality test determines whether the research data is normally distributed. The homogeneity test determines whether two groups come from the same population or have the same variance. The t-test determines whether there is a significant difference between two groups on a particular variable.

Ho = there is no significant difference between pre-test and post-test

Ha = there is a significant difference between pre-test and post-test

The statistical results for the normality test, homogeneity test, and t-test are presented in Tables 4, 5, and 6.

Table 4. Normality Test

Data	Statistic	df	Sig.
Posttest	0.081	115	0.058
Pretest	0.067	115	0.200

The normality test of the pre-test data produced a value of 0.058, and the post-test data produced a value of 0.200. These values are smaller than 0.05, so the pre-test and post-test data are normally distributed.

Table 5. Homogeneity Test

Levene Statistic	df1	df2	Sig.
0.766	1	228	0.382

The homogeneity test of pre-test and post-test data produced a value of 0.382. This value is greater than 0.05, so the pre-test and post-test data are homogeneous or come from the same population.

Table 6. Paired T-test

Measure 1		Measure 2	t	df	p	Cohen's d	SE Cohen's d
Pre-test	-	Post-test	-61.933	114	< .001	-5.775	0.505

The results of the paired t-test showed a t-value of -61.933. There is a vast difference between the two groups of data (pre-test and post-test). A negative t-value indicates that the post-test score is significantly higher than the pre-test. A p-value less than 0.001 indicates that this result is statistically significant, meaning the difference between the pre-test and post-test scores is very significant. Cohen's d measures the effect size or how big the difference is between two groups of data. A d value of -5.775 indicates a substantial effect between the pre-test and post-test.

Pearson correlation coefficient was conducted to determine the relationship between fluency, flexibility, originality, and elaboration indicators. The results of the Pearson correlation test are presented in Table 7 and illustrated in Figure 2.

Table 7. Pearson Correlation Coefficient

Indicator		Fluency		Flexibility		Originality		Elaboration
Flexibility	n	115						
	Pearson's r	0.774	***					
	p-value	< .001						
	Effect size (Fisher's z)	1.029						
	SE Effect size	0.094						
Originality	n	115		115		—		
	Pearson's r	0.687	***	0.724	***	—		
	p-value	< .001		< .001		—		
	Effect size (Fisher's z)	0.841		0.915		—		
	SE Effect size	0.094		0.094		—		
Elaboration	n	115		115		115		—
	Pearson's r	0.526	***	0.694	***	0.763	***	—
	p-value	< .001		< .001		< .001		—
	Effect size (Fisher's z)	0.584		0.856		1.003		—
	SE Effect size	0.094		0.094		0.094		—

* p < .05, ** p < .01, *** p < .001

Table 7 and Figure 2 show the correlation of fluency, flexibility, originality, and elaboration. Pearson correlation coefficient (r) measures the strength and direction of the linear relationship between indicators with values ranging from -1 to +1. Positive values indicate a positive relationship and negative values indicate a negative relationship. The correlation between fluency and flexibility is 0.774 with p < 0.001, indicating a strong and statistically significant relationship; the higher the fluency, the higher the flexibility.

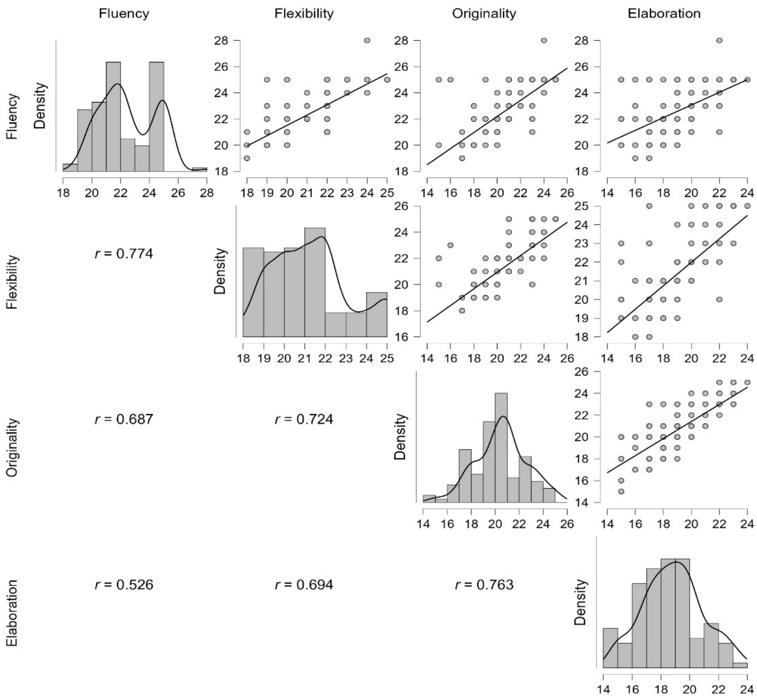

Figure 2. Correlation of Creative Thinking Skills Indicators

The effect size (1.029) indicates a significant impact of this relationship. The correlation between fluency and originality is 0.687 with $p < 0.001$, indicating a relatively strong relationship with an effect size of 0.841. This value indicates that high fluency tends to be associated with high originality.

The correlation between fluency and elaboration is 0.526, with $p < 0.001$. This relationship is weaker than the previous two but still significant, with an effect size of 0.584. The effect size uses Fisher's z transformation to assess the significance of the relationship between two indicators. The larger the z value, the stronger the effect or impact of the relationship. Flexibility and originality have the most significant effect size (1.003), indicating a powerful relationship. Fluency and flexibility also have significant effect sizes (1.029), indicating a powerful relationship. The effect size between flexibility and elaboration is 0.856, indicating a strong and statistically significant relationship. All p-values are below 0.001, indicating that all relationships between indicators are statistically significant.

The results of qualitative data analysis based on the recapitulation of observations and interviews using aspects of understanding UbD to develop creative thinking skills are presented in Table 8.

Table 8. Recapitulation of Observations and Interviews

No	Aspect	Observation	Interview
1	Explanation	Students explained concepts fluently and in a structured manner and demonstrated good understanding.	Students agree and support that case-based learning with the UbD framework provided an authentic context that made the concepts easier to understand.
2	Interpretation	Students saw possibilities and adapted their approach to the problems in detail.	Students agree and support that case-based learning with the UbD framework helped them understand the concept of the ideal gas law in detail.
3	Application	Students generated solutions in various cases	Students learned how to apply the ideal gas law in various situations.

4	Perspectives	Students demonstrated flexibility in considering various perspectives when solving problems in cases.	Some students had difficulty in linking concepts to cases.
5	Empathy	Students empathized with the challenges in the cases given.	Students agree that discussions with friends and lecturer guidance helped them overcome their difficulties.
6	Self-knowledge	Students adapted and responded well to various questions.	Students agree that working in groups was very helpful in understanding the material.

Time constraints often increase students' cognitive load, particularly in environments that emphasize quick, creative thinking, such as Case-Based Learning (CBL). CBL promotes the rapid generation of innovative ideas, which may inadvertently prioritize creating unique ideas over the depth of elaboration. Students are likely to prioritize generating novel ideas due to the pressure of limited time, thereby sacrificing the thoroughness that detailed elaboration entails. Sweller et al. (2019) support the cognitive load theory, which suggests that when students encounter stringent time limits, cognitive resources become strained, making deeper engagement with ideas challenging. This aligns with Hanke (2011), which indicates that lesson design creativity often leads to innovative approaches but may falter in detailed execution, reflecting the struggle with cognitive constraints in elaboration processes.

Case-Based Learning (CBL) fosters critical thinking and problem-solving by immersing students in authentic scenarios necessitating analysis, evaluation, and creative solution development. A study demonstrated that CBL enhances student engagement and problem-solving abilities by allowing students to resolve complex issues actively, strengthening their critical thinking skills across diverse contexts, including disaster scenarios presented through animated videos (Lara-Prieto & Flores-Garza, 2022). CBL is a dynamic instructional model that stimulates interest and deepens understanding through reflective inquiry and collaborative learning (Wen et al., 2024). For instance, leveraging case studies enables students to encounter real-world problems, prompting the development of innovative solutions that account for the unpredictability and multifaceted nature of actual challenges (Kong et al., 2025).

The Cognitive Load Model (CLM) generally emphasizes generating diverse and innovative solutions rather than in-depth elaboration, potentially hindering students' ability to develop ideas thoroughly (Khanova et al., 2015). If the instructional framework includes brainstorming activities without adequately guiding students toward deep exploration of their ideas, elaboration may suffer. This finding is corroborated by Khanova et al. (2015), underscoring the necessity for thoughtful design and assessment restructuring to achieve instructional alignment in various educational settings. An instructional model that encourages rapid idea generation without follow-ups or systematic elaboration may lead students to excel in originality but lag in detail-oriented tasks.

Elaboration is widely recognized as a pivotal dimension of creative thinking, indicative of an individual's ability to develop ideas comprehensively (Liu et al., 2024). Despite its importance, empirical assessments often reveal that scores for elaboration trail behind those for fluency, flexibility, and originality (Saputri et al., 2022). This disparity raises questions regarding the factors that impact elaboration, necessitating exploring personal experiences, time limitations during assessments, and the methodological issues surrounding its evaluation. Several key factors contribute to the underperformance of elaboration in creative assessments. Personal experience is critical in shaping an individual's ability to elaborate on ideas. Students with more extensive exposure to creative tasks are better at articulating detailed and nuanced thoughts (Tamirrino et al., 2023). In parallel, time constraints during creative assessments can inhibit the elaborative process, as individuals may feel pressured to produce quick responses rather than allowing their ideas to develop fully (Madyani et al., 2020). Consequently, the urgency can stifle creativity and result in superficial elaboration.

Student motivation plays a pivotal role in emphasizing originality over elaboration. Students often find generating novel ideas more stimulating than developing existing ideas, perceiving the latter as less engaging or important (Roskes, 2015). This notion aligns with Roskes (2015) that certain constraints can channel cognitive resources, enhancing creative output but potentially obscuring the value of detailed elaboration. Furthermore, many students may not comprehend the significance of elaboration in problem-solving tasks, viewing it as secondary to the excitement of brainstorming innovative ideas. Educators can provide guidance and support to address this misunderstanding, fostering a broader appreciation for the intricacies of originality and elaboration (Roskes, 2015; Fischer et al., 2023).

Case-based learning is a student-centered approach that enables them to evaluate clinical scenarios and actively address challenges (Shohani et al., 2023; Xu et al., 2024). This learning can improve various competencies in undergraduate and postgraduate students (Aggarwal et al., 2024). Implementing CBL facilitates deep learning, provides learning experiences, and helps students collaborate actively (McLean, 2016; Loftus, 2022; Maia et al., 2023) so students' creative thinking skills can be realized. Students can develop critical thinking skills, as seen from students' ability to answer creative thinking skills tests correctly on the following indicators: explaining concepts accurately, interpreting information or data in detail, applying concepts in various cases, providing different perspectives in different cases, empathizing with the concept, and reflecting a unique and original understanding of concepts.

The results of the statistical description show students' overall creative thinking skills. The fluency indicator has a higher value than other indicators. This success is driven by implementing case-based learning with the UbD framework, which applies the understanding aspect. The application of CBL with the UbD framework has a positive impact on students' creative thinking skills, as seen from the difference between the pre-test and post-test scores, which reflect the difference before and after the implementation of CBL with the UbD framework (Chumak et al., 2022; Rizal et al., 2022). This difference also emphasizes the importance of CBL with the UbD framework in developing students' creative thinking skills and supporting their application in other learning contexts. With CBL and the UbD framework, students gain and apply new experiences in everyday life.

Meanwhile, the Pearson correlation coefficient shows that fluency strongly correlates with flexibility and originality. This result supports the theory that individuals more fluent in thinking tend to be more flexible in creating various solutions and producing more original ideas (Astawan et al., 2023). Elaboration had a slightly lower correlation with other indicators, especially with fluency, which could indicate that the ability to elaborate ideas does not depend entirely on fluency of thinking or flexibility (Wikara et al., 2022). These data show a significant and strong relationship between fluency, flexibility, originality, and elaboration. The most substantial relationship between flexibility and originality supports creative thinking skills. Flexibility is crucial for generating new and unique ideas (Apriwanda & Hanri, 2022). Several studies also show a relationship between fluency, flexibility, originality, and elaboration (José & Garrido, 2024; Koutstaal et al., 2024).

The results of observations and interviews show that students are involved in understanding and feeling the experiences of others in the context of learning (Wiggins & McTighe, 2011). These results support findings suggesting that CBL enhances students' understanding of different perspectives (Cheng et al., 2024). Interviews revealed that students better understood aspects of their creative thinking skills thanks to CBL with the UbD framework. Self-awareness in UbD includes reflection on individual skills and shortcomings in the context of learning (Ozyurt et al., 2023). Self-reflection driven by CBL with the UbD framework helps students evaluate and improve their creative skills. In addition, self-reflection also shows students thinking and acting in solving problems during the learning process.

Several studies show CBL as an alternative learning model that engages students by integrating theory into everyday life (Sood et al., 2021; Arab & Saeedi, 2024). CBL uses daily cases to help students improve problem-solving and decision-making (Chao et al., 2024). The success of CBL is generally considered to be a result of contextualizing theoretical concepts in a learning environment that engages students (Herreid & Schiller, 2013; Emblen-Perry, 2022). Contextualizing abstract concepts in the ideal gas law through implementing CBL with the UbD framework in classroom learning activities enables students to develop more creative problem-solving skills and connect theoretical concepts with real-life scenarios more effectively.

Case-based learning with the UbD framework can generally improve creative thinking skills, but some students have not shown significant development (Gube & Lajoie, 2020). Students' less-than-optimal creative thinking skills are caused by their difficulty in learning the ideal gas law due to implementing CBL with the UbD framework, which is influenced by several factors. Previous research shows that it is important to analyze learning using other theories to ensure the proper perspective and cover various categories (Seymour et al., 2023). Each individual requires attention, especially to factors that hinder learning goals, especially creative thinking skills, such as involvement in group discussions, motivation to learn, or academic background (Wisniewski et al., 2020). Other unmeasured variables may influence the research findings, such as the CBL learning process with the UbD framework, students' prior knowledge or training, or students' level of motivation (Chao et al., 2024).

With the integration of case-based learning and the Understanding by Design (UbD) framework, this research contributes to developing learning models in physics, especially in the concept of ideal gas law. Learning methods with this approach can improve students' creative thinking skills on the indicators of fluency, flexibility, originality, and elaboration needed in the era of globalization (Rahayu et al., 2022). Case-based learning shows that students can relate theory to everyday life (Zhao et al., 2020), especially when applying the ideal gas law to everyday problems. In previous research, UbD was often used in the humanities, such as literature, art, and behavior (Scale & Bilgileri, 2024), so this research opens up new opportunities for the flexibility of this framework in various disciplines, including physics. In addition, this research can be a model for further research by applying it to other physics concepts.

This study has limitations, including its limited scope and generalizability to other subjects or student populations. It focuses solely on Case-Based Learning (CBL) and creative thinking skills within the Ideal Gas Law, making the findings less applicable. The absence of pre-test data prevents measuring learning improvement, and the effectiveness of CBL and the Understanding by Design (UbD) framework may vary depending on the instructor's facilitation skills. Assessing creativity involves subjectivity, even with standardized rubrics, which may introduce rater bias. Time constraints and cognitive load could have influenced student responses, prioritizing originality over elaboration. Potential biases include selection bias, confirmation bias, and response bias. The instructor's enthusiasm for CBL might influence student engagement, affecting outcomes. Future studies should use diverse samples, pretest-posttest designs, double-blind scoring, and anonymous feedback to enhance validity and reliability.

CONCLUSION

Implementing case-based learning (CBL) with the Understanding by Design (UbD) framework to improve creative thinking skills on the ideal gas law showed positive results. This study revealed that CBL with the UbD framework effectively improves students' creative thinking skills, such as fluency in explanation, flexibility in interpretation and perspective, and originality in application. However, some students still face challenges linking the ideal gas law to cases, so they need additional guidance. Group discussions and lecturer guidance have proven to help solve problems. However, a more in-depth and structured approach is still needed to ensure all students can maximize CBL with the UbD framework. Attributing the gains in creative thinking to the UbD approach necessitates a comprehensive understanding of the learner's background and motivations. Future studies must meticulously adjust for these variables to draw more robust conclusions regarding the UbD framework's efficacy in fostering creative problem-solving within the context of science education. By adopting more methodologically sound research designs, we may better understand the role of instructional practices in enhancing student creativity. This study contributes to physics education as an alternative student-centered learning and allows educators to explore similar approaches in other fields. This study also impacts improving the quality of learning in higher education and students' 21st-century skills in the era of globalization.

REFERENCES

Angelo, T. (2021). Designing subjects for deeper learning: practical research-based principles and guidelines. In University Teaching in Focus (pp. 29-52). Routledge.

Aggarwal, V., Behal, P., Sharma, V., Yadav, A. K., & Yanamandra, U. (2024). To study the efficacy of case based learning on prescription practices in post graduate students on geriatric patients attending medical OPD. *Medical Journal Armed Forces India*.

Alani, F., Geng, F. E. I., Toribio, M. A. E., & Grewal, R. (2022). *Effect of Case-Based Learning (CBL) on Student Performance in Engineering Biotechnology Education , 38*(2), 543–548.

Angel, L. G. B. M., Quesada, A. R., Suárez, F., & José, F. (2021). *A problem- / case-based learning approach as an useful tool for studying glycogen metabolism and its regulation. March 2020*, 236–241.

Apriwanda, W., & Hanri, C. (2022). *LEVEL OF CREATIVE THINKING AMONG PROSPECTIVE*

CHEMISTRY TEACHERS. *11*(2), 296–302.

Arab, F., & Saeedi, M. (2024). The effect of the case-based learning approach on the level of satisfactions and learning of nursing students in Iran: A randomized controlled trial. *Heliyon*, *10*(15), e35149.

Aytaç, T., Kula, S. S., & The, S. S. (2020). *The Effect of Approaches on Students ' Creative Thinking Skills : A Meta-Analysis Study To cite this article : The Effect of Student-Centered Approaches on Students ' Creative Thinking Skills : A Meta-Analysis Study*.

Barnes, V., Theo, L. J., & Eriksson, V. (2024). Towards a definition of 'empathic understanding' in industrial design practice. *The Journal for Transdisciplinary Research in Southern Africa*, *20*(1), 1–12.

Bharathi, S. V., & Pande, M. B. (2024). Does constructivism learning approach lead to developing creative thinking skills? The mediating role of online collaborative learning environments. In *Journal of Computers in Education* (Issue 0123456789). Springer Berlin Heidelberg.

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, *11*(4), 589–597.

Burgess, A., Matar, E., Roberts, C., Haq, I., Wynter, L., Singer, J., Kalman, E., & Bleasel, J. (2021). *Scaffolding medical student knowledge and skills : team-based learning (TBL) and case-based learning (CBL)*. 1–14.

Çetinkaya, L. (2024). *Assessing the Effectiveness of Case-Based Learning and Concept Mapping Approaches in Developing Theoretical and Metacognitive Skills in Medical Students*.

Chao, C.-T., Wu, M.-Y., Hung, K.-Y., Wu, M.-S., & Liang, J.-C. (2024). Interprofessional Differences in Multidimensional Self-Efficacy Associated With Professional Performance in Nephrology During Case-Based Learning. *Kidney International Reports*, *9*(4), 877–887.

Cheng, S., Cheng, C., Hung, C., & Chang, P. (2024). Effect of case-based teaching videos on e-learning platforms on the self-regulated learning outcomes of students. *Social Work Education*, *00*(00), 1–21.

Chumak, M., Nekrasov, S., Hrychanyk, N., Prylypko, V., & Mykhalchuk, V. (2022). *Applying Case Method in the Training of Future Specialists*, *11*(1), 235–244.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research (3rd ed.). SAGE Publications.*

Davison, M. (2017). Teaching about the First World War today: Historical empathy and participatory citizenship. *Citizenship, Social and Economics Education*, *16*(3), 148–156.

Emblen-Perry, K. (2022). Auditing a case study: Enhancing case-based learning in education for sustainability. *Journal of Cleaner Production*, *381*, 134944.

Eren-Şişman, E.N., Çiğdemoğlu, C., Kanlı, U. et al. (2020). *Science Teachers ' Professional Development about Science Centers*, 1255–1290.

Fischer, K., Sullivan, A. M., Cohen, A. P., King, R. W., Cockrill, B. A., & Besche, H. C. (2023). Using cognitive load theory to evaluate and improve preparatory materials and study time for the flipped classroom. *BMC Medical Education*, *23*(1), 1–11.

Fuentes, M. C., Garcia, O. F., Alcaide, M., Garcia-Ros, R., & Garcia, F. (2022). Analyzing when parental warmth but without parental strictness leads to more adolescent empathy and self-concept: Evidence from Spanish homes. *Frontiers in Psychology*, *13*(December), 1–15.

Gube, M., & Lajoie, S. (2020). Adaptive expertise and creative thinking : A synthetic review and implications for practice. *Thinking Skills and Creativity*, *35*(August 2019), 100630.

Hanke, U. (2011). Effects of Creative Dispositions on the Design of Lessons. *The Open Education Journal*, *4*(1), 113–119.

Henriksen, D., Creely, E., Henderson, M., & Mishra, P. (2021). *Creativity and technology in teaching and learning : a literature review of the uneasy space of implementation*. *0123456789*.

Hernandez-de-Menendez, M., Morales-Menendez, R., Escobar, C. A., & McGovern, M. (2020). Competencies for Industry 4.0. *International Journal on Interactive Design and Manufacturing*, *14*(4), 1511–1524.

Herreid Clyde Freeman, & Schiller Nancy A. (2013). Case Studies and the Flipped Classroom. *Journal of College Science Teaching*, *42*(5), 62–66.

I. G. Astawan, I. M. Suarjana, B. R. Werang, S. I. Asaloei, M. Sianturi, E. C. E. (2023). *STEM-BASED SCIENTIFIC LEARNING AND ITS IMPACT ON STUDENTS ' CRITICAL AND CREATIVE THINKING SKILLS : AN EMPIRICAL STUDY*. *12*(3), 482–492.

José, A., & Garrido, L. (2024). *Indicators of verbal creative thinking : results of a Delphi panel*. *July*, 1–8.

Khanova, J., Roth, M. T., Rodgers, J. E., & McLaughlin, J. E. (2015). Student experiences across multiple flipped courses in a single curriculum. *Medical Education*, *49*(10), 1038–1048.

Kong, W., Huang, Y., Lu, Y., Shen, X., Luo, C., Zhang, B., Lin, Y., Chen, S., Li, X., Han, F., Chen, J., & Xu, Y. (2025). Development, implementation and evaluation of consultation case-based learning course to improve the interdisciplinary clinical reasoning ability-a pilot study from nephrology. *BMC Medical Education*, *25*(1), 121.

Koutstaal, W., Brown, L., Lu, K., Posson, K., Koutstaal, W., Brown, L., Lu, K., & Posson, K. (2024). Beyond Openness : A Variety of Creative Experiences Increases Flexibility and Originality of Visuospatial Divergent Thinking Beyond Openness : A Variety of Creative Experiences Increases Flexibility and Originality of Visuospatial Divergent Thinking. *Creativity Research Journal*, *00*(00), 1–21.

Lara-Prieto, V., & Flores-Garza, G. E. (2022). iWeek experience: the innovation challenges of digital transformation in industry. *International Journal* *on Interactive Design and Manufacturing*, *16*(1), 81–98.

Lavi, R., & Marti, D. (2023). A Proposed Case-Based Learning Framework for Fostering Undergraduate Engineering Students' Creative and Critical Thinking. *Journal of Science Education and Technology*, *32*(6), 898–911.

Li, M., & Tu, C. (2024). *education sciences Developing a Project-Based Learning Course Model Combined with the Think – Pair – Share Strategy to Enhance Creative Thinking Skills in Education Students*.

Liu, W., Huang, R., Wang, J., Chen, Y., Ohashi, T., Li, B., Liu, Y., Qiu, D., Yu, R., Zhang, J., Al Mahmud, A., & Leifer, L. (2024). Empathy Design Thinking: cultivating creative minds in primary education. *Frontiers in education*, *9*.

Loftus, S. (2022). Case-based learning. In An Introduction to Medical Teaching: The Foundations of Curriculum Design, Delivery, and Assessment (pp. 99-113). Cham: Springer International Publishing.

Lumbreras, R., & Rupley, W. H. (2020). *Pre-service teachers ' application of understanding by design in lesson planning*. *9*(3), 594–599.

Madyani, I., Yamtinah, S., Utomo, S. B., Saputro, S., & Mahardiani, L. (2020). *Profile of Students' Creative Thinking Skills in Science Learning*. *397*(Icliqe 2019), 957–964.

Maggiore, N. M., Powers, K. P., Lwanga, K. L., & Gnann, I. C. (2024). The impact of learning assistant facilitation practices on student in - the - moment learning. In *International Journal of STEM Education*. Springer International Publishing.

Maia, D., Andrade, R., Afonso, J., Costa, P., Valente, C., & Espregueira-Mendes, J. (2023). Academic performance and perceptions of undergraduate medical students in case-based learning compared to other teaching strategies: a systematic review with meta-analysis. Education Sciences, 13(3), 238.

McKinnon, J. (2018). In their shoes: An ontological perspective on empathy in nursing practice. *Journal of Clinical Nursing*, *27*(21–22), 3882–3893.

McLean, S. F. (2016). Case-based learning and its application in medical and health-care fields: a review of worldwide literature. Journal of medical education and curricular development, 3, JMECD-S20377.

Mcniven, S. B. A. L., Balogh, A. B. J. M., & Tsao, M. N. (2023). Evolution and Evaluation of a Structured Applied Physics Course for Radiation Oncology and Radiation Physics Trainees. *Journal of Cancer Education*, *38*(3), 813–820.

Meyer, E. S., Green, J. L., Arnold, E. G., & Wickstrom, M. H. (2024). Understanding How and When Graduate Student Instructors Break Through Challenges with Active Learning. In *International Journal of Research in Undergraduate Mathematics Education* (Issue 0123456789). Springer International Publishing.

Oo, T. Z., Kadyirov, T., & Kadyjrova, L. (2024). *Design-based learning in higher education : Its effects on students ' motivation , creativity and design skills*. *53*(March).

Ozyurt, M., Kan, H., & Kiyikci, A. (2023). *The Effectiveness of Understanding by Design Model in Science Teaching : A Quasi-experimental Study*. *January*.

Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice (4th ed.). SAGE Publications.*

Raza, S. A. (2020). *Examining the impact of case-based learning on student engagement , learning motivation and learning performance among university students*. *12*(3), 517–533.

Rizal, S., Putra, A. K., Suharto, Y., & Wirahayu, Y. A. (2022). *CREATIVE THINKING AND PROCESS SCIENCE SKILL: SELF-ORGANIZED LEARNING ENVIRONMENT ON WATERSHED CONSERVATION MATERIAL*. *11*(4), 578–587.

Roskes, M. (2015). Constraints that Help or Hinder Creative Performance: A Motivational Approach. *Creativity and Innovation Management*, *24*(2), 197–206.

Rudzińska, A., Guzy, P., Skowron, A., Gąsowski, J., & Piotrowicz, K. (2024). Joint interprofessional education of pharmacy and dietetics undergraduates - a scoping review. *BMC Medical Education*, *24*(1), 1–11.

Runco, M. A., & Garrett J., J. (2012). The Standard Definition of Creativity. *Creativity Research Journal*, *24*(1), 92–96.

Runco, M. A., Millar, G., Acar, S., & Cramond, B. (2010). Torrance tests of creative thinking as predictors of personal and public achievement: A fifty-year follow-up. *Creativity Research Journal*, *22*(4), 361–368.

S. Rahayu, P. Setyosari*, A. Hidayat, D. K. (2022). *THE EFFECTIVENESS OF CREATIVE PROBLEM SOLVING-FLIPPED CLASSROOM FOR ENHANCING STUDENTS ' CREATIVE THINKING SKILLS IN ONLINE PHYSICS EDUCATIONAL LEARNING*. *11*(4), 649–656.

Saputri, M., Syukri, M., & Elisa. (2022). Analysis of momentum and impulse on students' creative thinking skill through project based learning integrated STEM (science, technology, engineering, mathematics). *Journal of Physics: Conference Series*, *2193*(1).

Scale, W., & Bilgileri, M. (2024). *Erzincan Üniversitesi Eğitim Fakültesi Dergisi Erzincan University Journal of Education Faculty 2024*. *2*(2021), 330–338.

Seymour, R., Scher, C., Frasso, R., Truong, S., Ziring, D., & Ankam, N. (2023). Exposing the disability-related hidden curriculum in case-based learning: A qualitative study. *Disability and Health Journal*, *16*(4), 101483.

Shohani, M., Bastami, M., Gheshlaghi, L. A., & Nasrollahi, A. (2023). Nursing student's satisfaction with two methods of CBL and lecture-based learning. *BMC Medical Education*, *23*(1), 48.

Sood, M., Kaur, K., & Arora, R. (2021). Introduction of case-based learning to teach Pharmacology to second year MBBS students. *International Journal of Basic & Clinical Pharmacology*, *10*(2), 176.

Steen, J. Van Der, Schilt, T. Van, Cees, M., & Desirée, V. D. V. (2023). Designing Formative Assessment That Improves Teaching and Learning : What Can Be Learned from the Design Stories of Experienced Teachers ? *Journal of Formative Design in Learning*, *7*(2), 182–194.

Sudibyo, E., Jatmiko, B., & Widodo, W. (2016). *The Effectiveness of CBL Model to Improve Analytical Thinking Skills the Students of Sport Science*, *9*(4), 195–203.

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review*, *31*(2), 261–292.

Tamirrino, N. G., Hendriana, H., & Hidayat, W. (2023). Analysis of Mathematical Creative Thinking Abilities of High School Students in West Bandung Regency. *(Jiml) Journal of Innovative Mathematics Learning*, *6*(2), 104–112.

Tirado, S., Carlota, O., & Fernández, L. (2024). Enhancing historical thinking through learning analytics in Primary Education : A bridge to formative assessment. *Education and Information Technologies*, *29*(12), 14789–14813.

Vani, A. C., Stephen, S., Anjana, V., Sreekala, P. L., Eranholi, P., & Rema, A. K. (2022). Using student-designed cases to foster creative and critical thinking skills in biochemistry. *Journal of Education and Health Promotion, 11*(1), 337.

Wang, M., Liang, S., & Jiang, T. (2024). Comparison of case-based and lecture-based learning in dental fluorosis diagnostic ability with visual analog scale assessment. *BMC Medical Education*, *24*(1), 1–11.

Wen, F., Mo, J., & Li, R. (2024). Application value of multi-disciplinary collaborative diagnosis and treatment combined with CBL teaching model in gynecological oncology practice teaching. *Frontiers in Medicine*, *11*(January), 1–9.

Wiggins, G. P., & McTighe, J. (2011). *The Understanding by Design guide to creating high-quality units. Alexandria, VA: ASCD.*

Wikara, B., Sutarno, S., Suranto, S., & Sajidan, S. (2022). *Jurnal Pendidikan IPA Indonesia IMPLEMENTATION OF 5E PLUS LEARNING MODEL ON ENERGY SUBJECT MATTER TO IMPROVE STUDENTS ' ARGUMENTATION SKILLS*. *11*(2), 237–245.

WIPO. (2024). Global Innovation Index 2024 Unlocking the Promise of Social g Entrepreneurship. In *Αγαη* (Vol. 15, Issue 1). WIPO.

Wisniewski, B., Zierer, K., Hattie, J., & Wang, L. (2020). *The Power of Feedback Revisited : A Meta-Analysis of Educational Feedback Research*. *10*(January), 1–14.

Xu, G., Lin, Y., Ye, Y., Wu, W., Zhang, X., & Xiao, H. (2024). Combination of concept maps and case-based learning in a flipped classroom: A mixed-methods study. *Nurse Education in Practice*, *76*, 103918.

Zhao, W., He, L., Deng, W., Zhu, J., Su, A., & Zhang, Y. (2020). *The effectiveness of the combined problem-based learning (PBL) and case- based learning (CBL) teaching method in the clinical practical teaching of thyroid disease*. 1–10.