MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2025, 21(5), em2628
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/16276

The role of inquiry learning in enhancing creativity generating ideas from a self-efficacy perspective

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Received 18 February 2025 ▪ Accepted 16 April 2025

Abstract
A creative idea plays a pivotal role in enabling individuals to navigate the challenges posed by technological advancements, particularly within the realm of education. This study aims to enhance students creativity in generating ideas (CGI) and to examine the relationship between these ideas and creative products (CP), while also considering the influence of self-efficacy. The research employs an intervention incorporating the process-oriented guided inquiry learning model, supported by the flipped classroom approach (POGIL+FC). A quasi experimental research design is utilized, with data analyzed using a dependent t-test, two-way ANOVA, and correlation tests. The study involves 137 eleventh-grade students. The findings indicate that the POGIL+FC intervention effectively enhances students creative idea generation, particularly in the subdimensions of fluency and originality. Moreover, SE influences variations in students perspectives and the diversity of their generated ideas, while a positive correlation is observed between idea generation and CP. The implications of this study are discussed in the conclusion section.

Keywords: creativity generating ideas, creative products, inquiry learning, flipped classroom, self-efficacy, chemistry learning

INTRODUCTION

Creativity plays a vital role in equipping individuals to navigate the challenges posed by technological advancements, particularly within the field of education. The ability to think creatively is essential for problem solving in various contexts (OECD, 2018; Thornhill-Miller et al., 2023). A key indicator of creativity in an individual is reflected in the production of novel ideas or tangible outputs (Wong et al., 2021). The development of creative ideas is facilitated through cognitive, chemical, and biological processes occurring in the brain (Heong et al., 2019).

Creativity in generating ideas (CGI) within the field of education plays a crucial role in learning success. Creative ideas in learning can be defined as the outcome of higher order thinking skills (Heong et al., 2012), which integrate experience (Han & Suh, 2020), new information, and prior knowledge to generate innovative responses in challenging situations (Keleş, 2022). Students who generate creative ideas are able to develop a deeper understanding of learning materials through diverse approaches (Almahdawi et al., 2021) and effectively solve the problems they encounter (Rahayu et al., 2022). Encouraging creative thinking and idea generation in learning not only supports students in overcoming academic challenges (Akmam et al., 2024) but also equips them with essential skills for success in the professional workforce (Thornhill-Miller et al., 2023). Furthermore, creative ideas can optimize students utilization of technology in learning (Choi et al., 2023; Zhao et al., 2021). However, efforts to enhance creative idea generation in the educational context continue to face several limitations. For instance, problem-based learning (PBL) methods primarily enhance fluency, or the number of ideas generated (Sukardi et al., 2022) and require instructors to induce cognitive conflict and provide feedback to facilitate students creative idea

This article is derived from the PhD thesis of the first author.

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Contribution to the literature

- This study examines the intervention of the process-oriented guided inquiry learning model, supported by the flipped classroom approach (POGIL+FC) in enhancing the quantity, quality, and relevance of creative ideas generated by students in solving problems within the context of chemistry learning. This research distinguishes itself from previous studies on creativity, which have predominantly focused on creative thinking without specifically addressing the characteristics and nature of the ideas produced.
- Furthermore, this study explores the relationship between CGI and the creative products (CP) developed by students in chemistry learning.
- The research problem is categorized into two key aspects: contextual chemistry problems and student-generated problems. This distinction differentiates the present study from previous research, which has primarily concentrated on contextual chemistry problems alone.

generation (Akaki & Maeno, 2024) during group discussions (Kenworthy et al., 2024). Additionally, virtual interaction technologies play a crucial role in fostering collaborative idea generation in online learning environments (Brucks & Levav, 2022; Choi et al., 2023). Moreover, students motivation and self-regulation must be considered to ensure the production of high quality ideas (Puente-Díaz & Cavazos-Arroyo, 2022; Wang et al., 2023). Therefore, education must place a strong emphasis on fostering students creative idea development through appropriate learning methodologies.

Currently, PBL has become a widely adopted teaching method among instructors in schools. Creative ideas are fundamental for solving problems presented through this pedagogical approach (Mashfufah et al., 2023), particularly in the context of chemistry learning (Sukardi et al., 2022). For instance, students are required to generate either abstract ideas (in written form) or concrete ideas (in the form of products) to address the problems they encounter (Heong et al., 2012). However, PBL is generally more suitable for higher education students who have developed strong cognitive abilities, as proficiency in analyzing problems and determining appropriate projects is a key factor in the effectiveness of this teaching method (Hung, 2019). Furthermore, the proficiency of teachers in providing scaffolding to support students must be considered to optimize their cognitive processes (Senisum et al., 2022; Wijnia et al., 2024), given that creative ideas emerge from existing knowledge (Cassotti et al., 2016) and learning experiences (Han & Suh, 2020). Considering these factors, it can be concluded that PBL is less suitable for senior high school students in the context of fostering creative ideas, as its effectiveness relies on individuals with well-developed cognitive processes and structured scaffolding from teachers.

Based on these requirements, POGIL is considered an appropriate teaching method for implementation. In addition to being problem based, the structured scaffolding provided by teachers within this method can optimize students cognitive processes in learning (Simonson, 2019). The knowledge acquired through cognitive processes can be applied to real life situations or problems, fostering the creative ideas necessary for generating solutions (Sreejun & Chatwattana, 2023). Beyond the classroom, students must also engage their cognitive processes outside of class to think creatively and relate their acquired knowledge to real world contexts (Herunata et al., 2025; Rahayu et al., 2022). Therefore, it is essential to ensure that students continue to utilize their cognitive processes both in and outside the classroom to generate high quality ideas. Given these needs and the constraints of classroom learning time set by the curriculum, it is necessary to maximize learning opportunities using the POGIL model. Through both in-class and out-of-class sessions, the FC approach has been proven to enhance learning effectiveness during in-class sessions (Baum, 2013). Furthermore, integrating POGIL with FC can further optimize students cognitive processes beyond regular classroom sessions (Bokosmaty et al., 2019).

The POGIL+FC teaching method is regarded as effective in motivating students to confidently generate creative ideas. In addition to well-developed cognitive processes, students self-confidence in learning is a key factor in their ability to produce creative ideas for problem solving (Xiang et al., 2025). Preliminary observations conducted on 72 senior high school students during chemistry lessons revealed that approximately 69.45% of students exhibited low or poor levels of creative idea generation. Many students perceived chemistry as a difficult subject, irrelevant to their future lives, and expressed skepticism regarding whether their learning efforts would yield meaningful outcomes. Therefore, it is crucial to examine self-efficacy (SE) as a construct representing students confidence in learning (Liu et al., 2024). Students with good SE are more likely to engage in cognitive processes, self-motivate their learning, and persist longer when working on challenging or uninteresting academic tasks (Choi et al., 2024).

Based on these limitations, it is essential to enhance students creativity in idea generation and examine the relationship between these ideas and CP in problem solving. Motivation and self-confidence are key factors

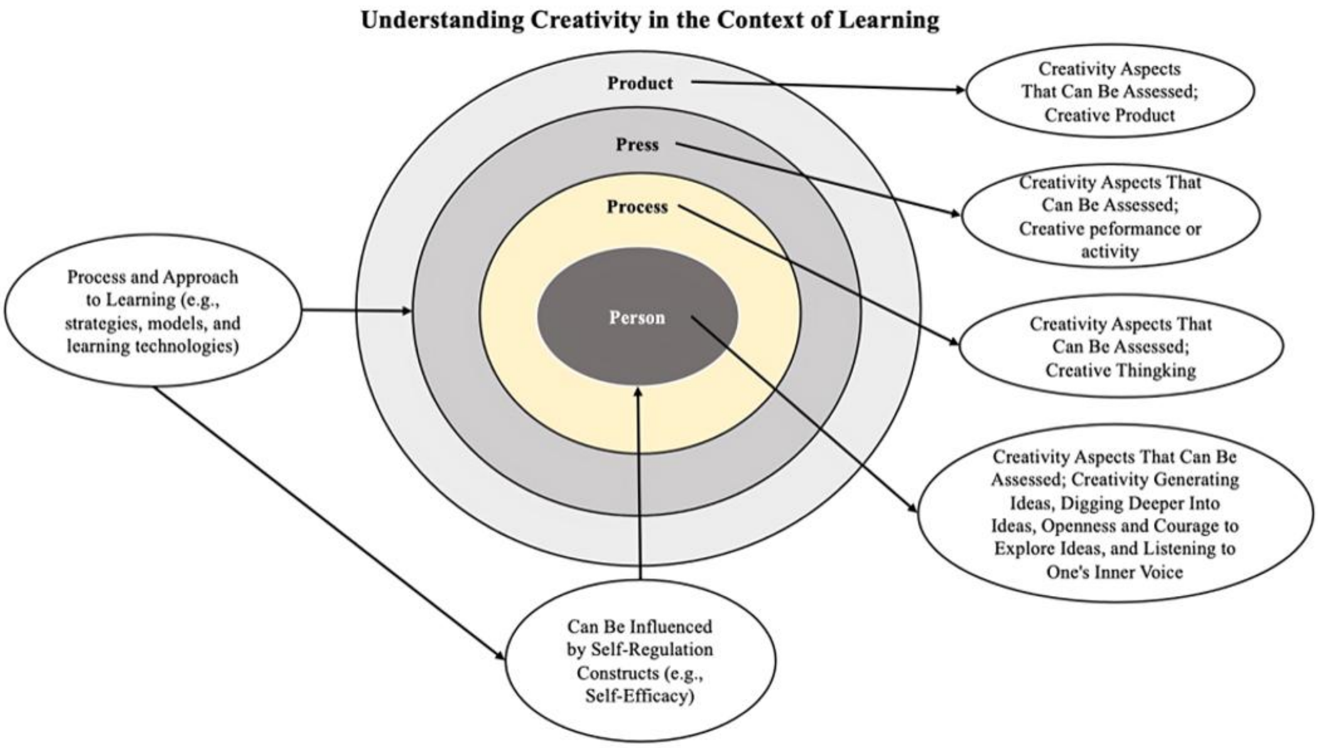


Figure 1. Aspects of creativity assessed based on Rhodes' (1961) theory (Source: Authors' own elaboration)

to consider in the generation of creative ideas, making SE a crucial aspect in assessing how variations in students confidence levels influence the ideas they produce. Given the critical role of instructors in PBL methods in stimulating cognitive conflict, this study compares the implementation of POGIL and PBL, both assisted by the FC approach, in fostering students creative ideas. This study aims to address the following research questions (RQs):

1. How does students CGI differ between those who receive POGIL+FC treatment and those who receive PBL+FC treatment?
2. How does CGI vary among students with different levels of SE?
3. How do POGIL and PBL, when assisted by FC, interact with SE in enhancing students CGI?
4. Is there a relationship between students CGI and the CP they produce to solve problems?

THEORITICAL BACKGROUND

Creativity Generating Idea & Product

There are four key pathways to understanding individual creativity tendencies: person, process, press, and product (see **Figure 1**) (Rhodes, 1961). A creative individual (person) possesses the ability to identify problems, generate ideas, and select the most appropriate ideas for implementation (Treffinger et al., 2002). Individuals with creative thinking skills utilize these ideas to develop problem solving strategies (process) (Cirkony, 2023; Mills et al., 2020). These ideas and strategies are influenced by environmental and situational factors (press), such as classroom teaching methods, workplace settings, or cultural influences. This is consistent with the findings of Kim et al. (2023) which indicate that the learning environment and cultural context significantly impact individuals' creative activities. The outcomes of problem solving can manifest as something novel, whether in abstract or concrete form (product).

According to Treffinger et al. (2002), personal creativity is categorized into four aspects, one of which is generating ideas (see **Figure 1**). CGI serves as a fundamental indicator of an individual's creativity (Treffinger et al., 2002). It is essential to analyze students creative ideas before exploring other aspects of creativity, such as CP (Treffinger et al., 2002), as CP serve as tangible representations of students cognitive processes in problem solving (Kim et al., 2023). Given the constraints of the research timeframe, this study focuses exclusively on the CGI aspect and its relationship with the CP produced by students.

Inquiry Learning

Inquiry based learning is a teaching method that encourages students to think creatively about contextual problems (Beghetto, 2021; Suwono et al., 2023). POGIL is a structured form of inquiry based learning designed to support students cognitive processes (Simonson, 2019). The POGIL learning framework consists of five stages, as outlined by Hanson (2015), orientation, exploration,

Table 1. Factorial analysis research design

Moderator variable	Instructional model (X)	
SE (Z)	POGIL+FC (X1)	PBL+FC (X2)
	CGI (Y1)	CGI (Y1)
Good (Z1)	X1Y1Z1	X2Y1Z1
Bad (Z2)	X1Y1Z2	X2Y1Z2
Total	X1Y1	X2Y1

Note. X1: POGIL+FC treatment; X2: PBL+FC treatment; Y1: CGI; Z1: Good SE; & Z2: Bad SE

concept invention, application, and closure. Scaffolding in POGIL is a crucial process that guides students in effectively utilizing their cognitive processes (Şen, 2024). The exploration and application stages challenge students to discover concepts for solving given problems (Alghamdi & Alotaibi, 2022). Meanwhile, the orientation and exploration stages play a vital role in motivating students and enhancing their confidence in learning (Vishnumolakala et al., 2017). Confidence in applying knowledge gained through structured cognitive processes enables students to generate creative ideas for problem solving in complex and challenging situations (Xiang et al., 2025).

Flipped Classroom

The FC approach divides the learning process into two phases, in-class and out-of-class sessions (Bergmann & Sams, 2011). Learning topics are provided to students one week prior to the lesson to facilitate independent preparation (Dehghanzadeh & Jafaraghaee, 2018; Utami et al., 2023). The integration of FC with POGIL is highly recommended, as scaffolding through key questions in POGIL can enhance classroom activities and serve as an alternative to instructional videos during out-of-class sessions (Sams & Bergmann, 2013). During in-class sessions, students engage in higher order cognitive tasks, such as applying, analyzing, evaluating, and creating solutions based on creative ideas (Dan & Mohamed, 2024; Zainuddin & Halili, 2016).

Self-Efficacy

SE refers to an individual’s belief in their ability to perform tasks and achieve goals using their existing skills and competencies. Individuals with a strong sense of SE are more likely to engage in cognitive processes (Pintrich & De Groot, 1990), demonstrate self-motivation, and exhibit creative thinking when solving problems (Liu et al., 2024). Students with good SE believe that the ideas they generate through knowledge and experience (cognitive processes) are the most appropriate solutions to problems (Puente-Díaz & Cavazos-Arroyo, 2022). This belief affects both the quality of their ideas and their perspective on idea generation (Semilarski et al., 2019). In contrast, students with bad SE tend to produce lower quality ideas, particularly when they frequently experience rejection from peers or group members (Ng et al., 2021). Thus, a supportive learning environment is essential for maximizing students SE (Bandura, 2002). POGIL can effectively enhance students SE in problem solving, as it fosters a structured and interactive small group learning environment (Vishnumolakala et al., 2017). The complexity of cognitive processes, learning environments, and students self-confidence or SE plays a critical role in facilitating creative idea generation (Case, 2022).

METHOD

The research design follows a quasi-experimental approach with a pretest-posttest design applied to both the control and experimental groups (Creswell, 2014). Statistical reasoning was assessed in both groups before and after learning the topics of chemical bonding and thermochemistry. Data from the pre-/post-test assessments in each group were analyzed both descriptively and inferentially to determine differences in students CGI (Creswell, 2014). In the experimental group, learning was conducted using the POGIL model, whereas in the control group, instruction was delivered through the PBL method. Both instructional approaches were supported by the FC model to enhance learning effectiveness. The research design is presented in **Table 1**.

Samples & Procedures

The cluster random sampling technique was employed to determine the sample for this study (Creswell, 2014). A total of 137 eleventh grade senior high school students enrolled in a chemistry course on chemical bonding and thermochemistry during the first semester of the 2024-2025 academic year participated in the study. The students were divided into an experimental group (n = 72) and a control group (n = 65). All samples were equivalent, as indicated by Levene test significance = 0.074, ensuring homogeneity between the groups. Informed consent was obtained from all participants, and the research objectives were explained to them in detail. The procedures and implementation of the study are presented in **Table 2**.

The topics of chemical bonding and thermochemistry were taught to both groups by instructors (teachers) from their respective schools. Before conducting the study, the research team first ensured the equivalence of the teachers delivering chemistry instruction in both the experimental and control classes. The teachers assigned

Table 2. Research implementation procedure

Component	POGIL+FC	PBL+FC
Instructor's role	Provides structured scaffolding and facilitates the learning process through discussion and questioning, guiding students to discover the correct concepts. The instructor acts not only as a facilitator but also as a discussion mediator.	Delivers instruction based on the established teaching model implemented in the school, acting solely as a facilitator without providing structured scaffolding.
Number of meetings	8 weeks (16 sessions)	8 weeks (16 sessions)
In-class session duration	90 minutes	90 minutes
Teaching materials	POGIL based student worksheets (LKPD)	Uses existing teaching materials provided by the school
Flipped classroom	Supported by FC	Supported by FC

Table 3. Implementation phase of the teaching method for the experimental and control groups

FC session	POGIL phase	PBL phase
Out-of-class	- Orientation - Exploration - Concept formation	- Follows teacher's guidelines
In-class	- Application - Closure	- Follows teacher's guidelines

to the POGIL+FC and PBL+FC groups were graduates of chemistry education programs with 10-15 years of teaching experience. The teacher in the experimental group received training in the implementation of POGIL+FC, following the steps outlined in the lesson plan. The training was conducted over two weeks, consisting of four sessions (with the chemistry topics covered in the training differing from those in the study).

Additionally, monitoring was carried out to ensure that the interventions provided by the teachers to the POGIL+FC and PBL+FC groups were distinct. The researchers ensured that both groups received both in-class and out-of-class sessions, during which students were required to complete a series of tasks and collaborative learning activities. This measure was taken to minimize research bias that could arise due to teacher influence (Creswell, 2014). In the PBL+FC group, students were given autonomy to formulate and test hypotheses based on chemical data gathered from learning materials, without direct guidance from the teacher. Subsequently, students interpreted their findings based on their understanding and prior knowledge during the final session of the lesson. In contrast, the POGIL+FC group followed a structured learning approach before the in-class session began. Students were required to complete several stages of the POGIL process in the LKPD (student worksheet) before attending the in-class session. Once the in-class session commenced, the teacher structured the discussion process and provided scaffolding to guide students in solving chemistry problems presented in the LKPD. The differences in the learning activities between the POGIL+FC and PBL+FC groups are presented in **Table 3**.

Data Collection Tools

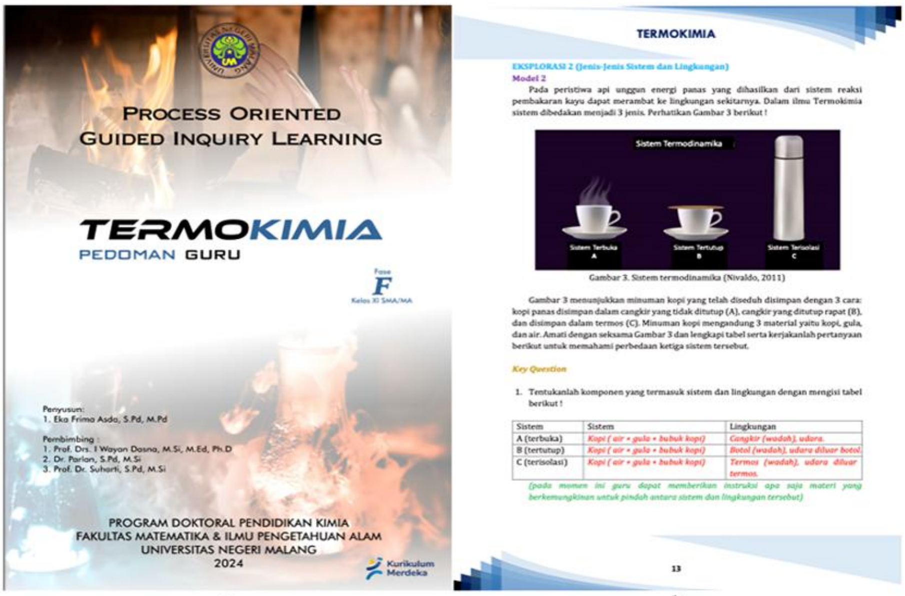
The instruments used in this study consisted of three data collection instruments and one learning instrument. These instruments were evaluated by eight experts with expertise in assessment, evaluation, and chemistry teaching. Based on the experts feedback, several items underwent wording modifications or editorial revisions, although no items were removed. The validation analysis conducted by the eight experts was assessed using Aiken V, categorizing the instruments as "valid for use". Subsequently, the instruments were trialed with a sample of 35 students to ensure their validity and reliability.

Creativity Generating Idea

The CGI instrument was developed by the research team based on the theory of Treffinger et al. (2002). A total of 10 statement items were designed to assess students creativity in the idea generation. The validity value (r-calculated) for each statement item exceeded the r-table value (0.334), and the reliability value using Cronbach's alpha was 0.783. Therefore, the CGI instrument was confirmed to be valid and reliable for measuring the construction of students CGI. Students creative ideas were assessed using the CGI instrument by observers, based on students written responses in the LKPD (student worksheets) and their explanations of their ideas. The assessment did not involve specialized interviews.

Creativity Product

The CP instrument was developed based on the theory of Besemer and Treffinger (1981). A total of 14 statement items were designed to evaluate the CP generated by students. Field validity and reliability tests were not conducted due to the extended time required for product creation. Instead, the validity test was carried out by eight experts and analyzed using Aiken's V. The expert evaluations categorized the instrument as "valid for use". Although it was not field tested, the expert panels assessment confirmed that the CP instrument was valid for measuring the CP construct.



a b

Figure 2. The POGIL worksheet on the topic of thermochemistry (Source: Authors' own elaboration)

Self-Efficacy

The SE instrument was adapted from Jinks and Morgan (1999). A total of 16 statement items were included in the instrument for this study. The validity value (r-calculated) for each statement item was greater than the r-table value (0.334), and the reliability value using Cronbach's alpha was 0.904. Therefore, the SE instrument was confirmed to be valid and reliable for measuring SE construct in students.

POGIL Worksheet

The POGIL worksheet on the topics of thermochemistry and chemical bonding was developed by the research team, aligning with the curriculum requirements in Indonesia and following the POGIL syntax developed by Hanson (2015), which includes orientation, exploration, concept formation, application, and closure. The teacher's role in guiding students to answer key questions and discover concepts is crucial within the learning flow designed in this POGIL worksheet. Part a and part b in **Figure 2** present the POGIL worksheet and exploration syntax, which contains key questions to guide students in discovering the concepts of thermochemistry. Students are required to answer the key questions in sequence to uncover the concepts. The red text in part b in **Figure 2** represents the answer key, which is exclusive to the teacher's POGIL worksheet guide, while the green text provides instructions for the teacher in case any issues arise during the lesson. The validity of the worksheet was tested by eight experts and analyzed using Aiken's V. After several stages of revisions, the final version of the worksheet was confirmed by the validators, resulting in a categorization of "valid for use." Therefore, the POGIL worksheet is deemed valid for fostering students ability to generate creative ideas.

Data Analysis

Data were analyzed using SPSS (statistical package for the social sciences). The statistical approaches employed included the t-test and two-way ANOVA. The assumption tests confirmed that the data were homogeneous (Levene test significance = 0.074) and normally distributed (Kolmogorov Smirnov significance = 0.200), allowing for further analysis using two-way ANOVA. Subsequently, correlation analysis was conducted to examine the relationship between CGI and CP. The normality test, conducted on a sample of 25 students, indicated that the data were not normally distributed (Shapiro Wilk test), with CGI = 0.004 and CP = 0.002. Consequently, correlation analysis was performed using a non-parametric approach, specifically Spearman's rank correlation analysis. The qualitative data in this study were analyzed through observation and documentation of the implementation of the teaching process, with the aim of providing a deeper understanding and strengthening the statistical findings regarding the context and processes occurring during the application of the method (Creswell, 2014). This approach offers a more comprehensive perspective on the overall interpretation of the research results.

RESULTS

RQ1. CGI of Students Differ Between Those Who Receive POGIL+FC and PBL+FC Treatment

The first stage of analysis was conducted exclusively on the POGIL+FC group. The results of the pre- and post-test comparison for the CGI construct indicated one sided t-test significance (p) and two sided t-test significance (p) values, both of which were < 0.001 (see **Table 4**).

Table 4. Results of the pre- and post-test of the POGIL+FC group

CGI	Paired differences					t	df	Significance	
	Mean	Standard deviation	Standard error mean	95% confidence interval of difference				One-sided p	Two-sided p
				Lower	Upper				
Pre-/post-test	-8.528	3.715	.438	-9.401	-7.655	-19.477	71	< .001	< .001

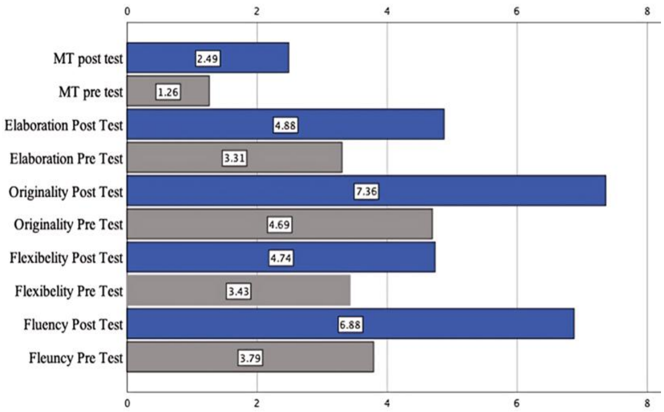


Figure 3. Differences in mean CGI scores of students in the POGIL+FC group (Source: Authors' own elaboration)

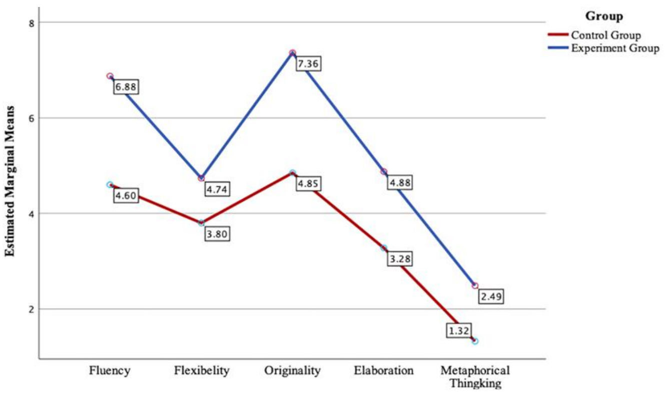


Figure 4. Differences in post-test CGI scores of students in the POGIL+FC and PBL+FC groups (Source: Authors' own elaboration)

Table 5. Two-way ANOVA test between POGIL+FC & PBL+FC with SE on CGI

Source	Type III sum of squares	df	Mean square	F	Significance	Partial eta squared
Corrected model	5,372.170[a]	7	767.453	139.008	< .001	.785
Intercept	63,754.671	1	63,754.671	11,547.841	< .001	.977
SE	197.028	1	197.028	35.688	< .001	.118
Group	2,136.450	3	712.150	128.991	< .001	.593
SE * Group	393.157	3	131.052	23.737	< .001	.211
Error	1,468.564	266	5.521			
Total	110,173.000	274				
Corrected total	6,840.734	273				

Note. Dependent variable: CGI & [a]R-squared = .785 (adjusted R-squared = .780)

This finding demonstrates a significant difference between students pre- and post-test creativity in the idea generation.

The CGI subdimensions are categorized into fluency, flexibility, originality, elaboration, and metaphorical thinking (MT). The post-test scores demonstrated an overall improvement across these subdimensions, as reflected in the mean values (see **Figure 3**).

A particularly notable difference was observed in the fluency and originality subdimensions. For instance, in the fluency subdimension, prior to the intervention, students exhibited limitations in generating ideas to comprehend the chemistry concepts being taught. However, after the intervention, students were able to generate ideas more fluidly within a specified time frame (2 minutes for fluency). This improvement is evident from the increase in pre-test fluency scores, which rose from 3.79 to 6.88. Conversely, the MT subdimension showed a relatively small improvement, indicating that students still faced challenges in illustrating chemistry concepts within the ideas they generated.

Table 5 indicates that the group component (POGIL+FC and PBL+FC treatments) has a significant impact on the differences in students CGI levels. The partial eta squared value of 0.593 suggests that approximately 59.3% of the variation in students creativity in idea generation can be attributed to the differences in treatment between the experimental and control groups. The differences in mean post-test scores between the POGIL+FC and PBL+FC groups are presented in **Figure 4**.

Based on **Figure 4**, the POGIL+FC group consistently achieved higher scores across all CGI subdimensions compared to PBL+FC group. A notable difference was observed in the fluency and originality subdimensions, where the POGIL+FC group attained scores of 6.88 and 7.36, respectively, while PBL+FC group only achieved 4.60 and 4.85. Conversely, MT subdimension exhibited the smallest difference between the two groups, although the POGIL+FC group still outperformed the PBL+FC group. These findings align with the previous analysis within the POGIL+FC group, where the most substantial improvements were observed in the fluency and originality subdimensions, whereas MT subdimension showed minimal improvement.

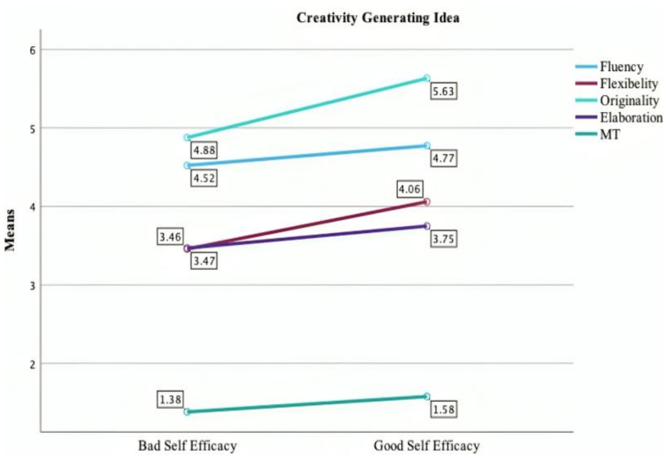


Figure 5. Differences students CGI based on variations in SE (Source: Authors' own elaboration)

RQ2. Differences in CGI Based on Variations in SE

Based on **Table 5**, differences in SE contribute to variations in students CGI in chemistry learning, with a significance value of < 0.001 (less than 0.005). The partial eta squared value of 0.118 indicates that SE accounts for 11.8% of the variability in students CGI. This effect is particularly evident in the originality and flexibility subdimensions, whereas fluency, elaboration, and MT show only minimal differences. Given that the observed effect is relatively small, it can be concluded that differences in SE primarily influence students idea variation (originality) and perspectives (flexibility) in idea generation (see **Figure 5**).

RQ3. Interaction Between SE and POGIL+FC in Influencing CGI Differences

Based on **Table 5**, an interaction effect was observed between the POGIL+FC teaching method and different levels of SE on students CGI. The significance value of < 0.001 and a partial eta squared value of 0.211 indicate that this interaction contributes 21.1% to the variability in students CGI levels. The interaction between POGIL+FC and good SE resulted in a substantial increase in students CGI scores, from 16.77 to 27.88. In contrast, students with the same SE level in the PBL+FC group showed only a marginal increase, from 17.15 to 17.38 (see **Figure 6**).

A positive interaction was also observed between POGIL+FC and students with bad SE, leading to an increase in CGI scores from 15.50 to 20.94. Meanwhile, students with bad SE in the PBL+FC group only showed a minor improvement, from 16.44 to 17.96. These findings suggest that the interaction between the POGIL+FC teaching method and SE has a notably positive impact on enhancing students CGI, particularly for individuals with good SE.

The analysis was further extended to examine the CGI subdimensions. An interesting interaction was observed among students with bad SE (see **Figure 7**).

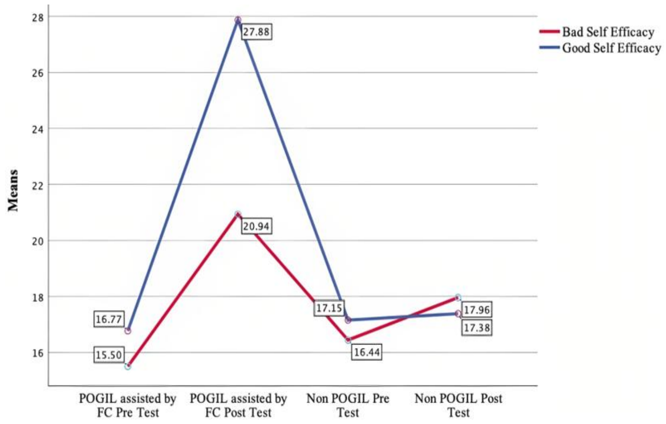


Figure 6. Interaction between teaching method and SE in relation to CGI (Source: Authors' own elaboration)

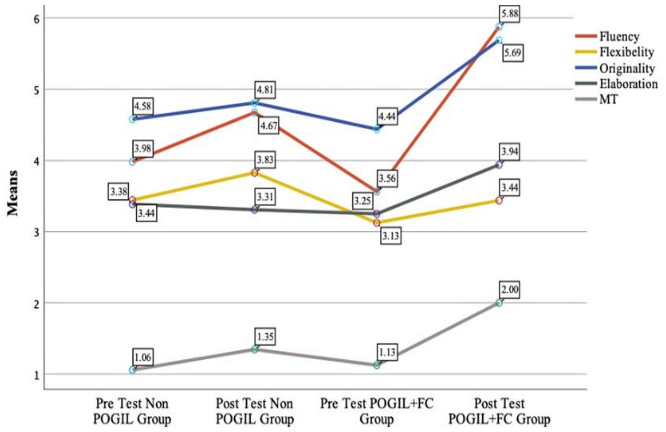


Figure 7. Interaction between teaching methods and bad SE in relation to CGI (subdimension analysis) (Source: Authors' own elaboration)

The mean post-test CGI score for the flexibility subdimension in the POGIL+FC group was lower (3.44) compared to the PBL+FC group (3.83). It can be observed from the lack of diversity in the functions of the ideas explained by the students in the LKPD. For example, in the context of problem B, a student suggested adding wood to increase the fire's intensity in order to cook faster. The same student then proposed adding kerosene (a type of fuel) for the same purpose. Although the ideas generated by the students were diverse, the intended outcome of these ideas was the same, which is rarely seen in the PBL+FC group. The PBL teaching method provides students with the opportunity to innovate, think creatively, and explore various solutions or products. This enables them to develop new thoughts and ideas that might not arise in more traditional teaching approaches. Therefore, the results of the post-test for POGIL+FC in the subdimension of Flexibility can be explained using the theory of cognitive flexibility. Further explanation will be discussed in the discussion section.

In contrast, students with good SE in the POGIL+FC group consistently achieved higher CGI scores compared to those in the PBL+FC group (see **Figure 8**).

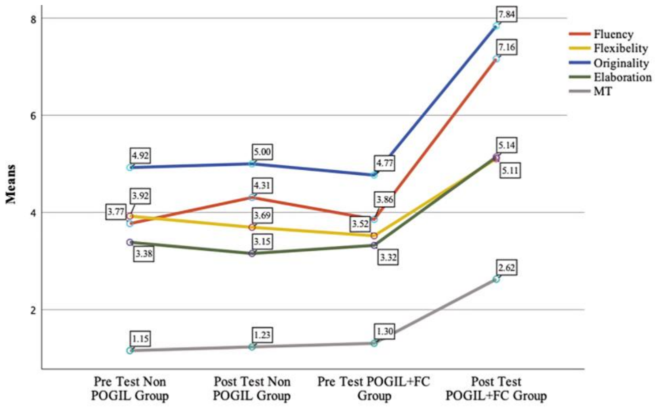


Figure 8. Interaction between teaching methods and good SE in relation to CGI (subdimension analysis) (Source: Authors' own elaboration)

Table 6. Correlation of CGI and CP

			CGI	CP
Spearman's rho	CGI	Correlation coefficient	1.000	.678**
		Significance (2-tailed)	.	< .001
		N	25	25
	CP	Correlation Coefficient	.678**	1.000
		Significance (2-tailed)	< .001	.
		N	25	25

Note. **Correlation is significant at the 0.01 level (2-tailed)

This finding supports Bandura (2002) theory, which states that individuals with good SE, when placed in a supportive environment, are more likely to achieve success in their intended goals.

RQ4. Relationship Between CGI and CP

The study was further extended to analyze the products created by students based on their generated ideas. Considering the constraints of instructional time and the current curriculum, a purposive sampling method was applied (Creswell, 2014), selecting 25 students to examine the correlation between CGI and CP. The Spearman correlation test revealed a positive relationship between CGI and CP, with a correlation coefficient of 0.678 (see **Table 6**). This indicates a positive association of 45.97% ($0.678^2 \times 100$) between students idea creativity and the CP they produce. The products generated by students were classified within the medium level (33.35%-66.70%). Given the limited time available for product development, achieving a medium level outcome on a 1-3 scale is considered satisfactory. This aligns with the meta-analysis by Da Cruz Alves et al. (2021), which suggests that the level of creativity in a product is significantly influenced by the duration of the creation process. Although the sample size analyzed was relatively small (25 students), these positive results can be developed and further investigated by future researchers to explore the relationship between creative ideas and the CP generated by students.

DISCUSSION

This study aims to examine the differences in students creativity generating ideas in learning chemistry using the POGIL+FC, considering different levels of SE. Additionally, it seeks to investigate the relationship between CP and CGI.

Differences in CGI Between POGIL+FC and PBL+FC Groups

The study of creativity in science learning, particularly in chemistry, should first consider the aspect of personal creativity, with a specific emphasis on creative thinking in idea generation. This aspect is essential for researchers and educators to gain a deeper understanding of students thought processes in learning chemistry. Moreover, CGI has been found to have a positive correlation with students overall creative abilities, including their capacity to produce CP. For example, in the original subdimension, students were given the opportunity to present their ideas in response to problems outlined in **Table 7** and **Table 8**. The data presented in **Table 7** and **Table 8** reflect students explanations of their ideas, as documented in the LKPD (student worksheet) and their verbal presentations in-class discussions. The observers assessed students creative ideas using the CGI instrument based on these two conditions. However, it is important to note that this assessment was not conducted using qualitative data analysis.

Table 7. Differences in students idea originality in understanding chemistry concepts

Student problem (A). How do students attempt to better understand and connect chemistry concepts they have learned with those they will learn?	
Student idea in the good CGI category (originality subdimension)	Originality assessment
*"… There are many ways I use to understand and connect chemistry concepts to my daily life. One approach is **utilizing** the LKPD (student worksheet) and e-books, as they allow me to study independently … I also apply the Pomodoro technique when studying with these materials, following a schedule of 50 minutes of study and 10 minutes of rest to maintain my concentration. During breaks, I reflect on the chemistry concepts I have learned. For instance, I **realized** that the type of metal used in a frying pan affects the speed at which food cooks …"*	- The idea is distinct from other students responses. - The problem solving approach is systematically structured. - The idea incorporates chemistry concepts relevant to the topic.
Student idea in the low CGI category (originality subdimension)	Originality assessment
"… I will ask the teacher or look it up on the internet when I get home ..."	- The idea is very general. It does not show an understanding of chemistry concepts.

Table 8. Differences in students idea originality in solving chemistry related problems

Thermochemistry topic problem (B). According to the Minangkabau people (one of the ethnic groups in Indonesia), rendang (a traditional dish) is best cooked using a traditional wood burning stove. However, this cooking process takes a considerable amount of time. ***Analyze*** *the cause of this and propose an idea to* ***optimize*** *the heat used in cooking rendang?*	
Student idea in the good CGI category (originality subdimension)	Originality assessment
"… The type of system in a wood-burning stove is an open system. Based on my understanding of different types of thermodynamic systems, an open system allows for rapid heat transfer from the system to the surroundings … to ***maximize*** *heat efficiency, the combustion system could be modified into a closed system. The covering material should be made of a poor heat conductor, such as clay, to prevent heat from dissipating into the environment. This way, heat is concentrated on the pan, which I believe would reduce cooking time by* ***optimizing*** *the heating process …"*	- The idea is distinct from other students responses. - The problem solving approach is systematically structured. - The idea is based on chemistry concepts related to thermodynamic systems.
Student idea in the low CGI category (originality subdimension)	Originality assessment
"… The combustion process in the stove can be improved by adding more fuel, such as wood, or by switching to liquefied petroleum gas (LPG) ..."	- The idea is very general. It does not show an understanding of chemistry concepts.

Based on **Table 7** and **Table 8**, it can be observed that students with a good CGI tend to have a systematic way of thinking when generating ideas and are able to correctly relate chemical concepts to these ideas. This difference aligns with the theory of Treffinger et al. (2002), which suggests that learning focused on cognitive processes (such as the POGIL teaching method) can enhance students creativity. Consistent with the study by Şen (2024), inquiry-based learning can support students in thinking creatively, especially in generating ideas (Cassotti et al., 2016). Furthermore, the teacher's role in the POGIL teaching method is also crucial in fostering students creative ideas. According to the study by Batlolona and Diantoro (2023), teacher preparation and instructional materials are vital factors in supporting students creative thinking processes. Teachers also need to manage the efficiency of the duration of POGIL learning sessions to maximize the teaching process (Bodner & Elmas, 2020). It can be concluded that the combination of POGIL with FC (POGIL+FC) can serve as a solution to develop students creative ideas in learning. The importance of creative ideas in education is supported by the findings of Almahdawi et al. (2021), which suggest that creative ideas can accelerate students understanding of the subject matter more deeply through alternative approaches and help them solve the challenges they encounter (Rahayu et al., 2022). Additionally, studies by Choi et al. (2023) and Zhao et al. (2021) further highlight that creative ideas can maximize the utilization of technology by students during their learning, particularly in chemistry education.

Based on the research findings, only a few students provided analogies of chemical concepts in the ideas they generated, which resulted in minimal differences in the MT subdimension, such as in the phrase 'spreading heat' (see **Table 8**). The limited improvement in students creativity in the MT subdimension may be attributed to a restricted conceptual understanding and learning duration. Therefore, to ensure that students conceptual understanding is adequate, it is necessary to extend the duration of learning using POGIL+FC, so that students can provide relevant analogies when explaining their ideas. Consistent with the findings of Sanchez-Ruiz et al. (2013), conceptual understanding influences how individuals make analogies and explain their thoughts (ideas) effectively (Farida et al., 2022; Yücel et al., 2010). These findings suggest that future studies on creativity in chemistry education should place greater emphasis on ensuring a solid conceptual understanding, enabling students to correctly analogize abstract chemical concepts.

Differences in CGI Based on Students Self-Efficacy

Based on the findings from RQ2, there is a difference in students CGI levels depending on their SE, with a variance of 11.8%. A significant difference was observed in the flexibility and originality subdimensions, indicating that SE influences the variation and perspective of students ideas in the idea generation. Refer to **Table 9** and **Table 10** for an analysis of the flexibility subdimension, which illustrates how different levels of SE impact students approach to problem solving (note: idea assessment and problem context are consistent with **Table 7** and **Table 8**). Based on **Table 9** and **Table 10**, it can be observed that differences in SE affect the perspective from which students generate ideas. Previous studies have shown that SE has a positive correlation with individual thinking effort (Gümüş et al., 2024; Kazu & Pullu, 2023) in generating ideas and creative thinking (Cassotti et al., 2016). According to Gümüş et al. (2024), the level of self-confidence helps students to view problems from different perspectives, then create ideas using the knowledge and experiences they already possess to solve those problems (Pepe, 2021; Semilarski et al., 2019). Also, according to Vishnumolakala et al. (2017), educators play a crucial role in building and supporting students SE, such as by providing positive feedback and creating a supportive learning environment, which encourages students to generate a variety of creative ideas, particularly in the context of chemistry education.

Table 9. Differences in students idea flexibility based on SE in problem context A

Student problem (A)	
Student idea in the good SE category (flexibility subdimension)	Flexibility assessment
*"… to understand thermochemistry concepts, I can create a scrapbook, allowing me to **organize** key concepts clearly and carry it with me, such as in my school bag. Sometimes, I also create concept maps to stick on my bedroom wall, so I can revisit the chemistry concepts I have learned whenever I take a break or before going to sleep …"*	- The idea incorporates multiple perspectives based on its functionality. - The students adapt their idea to suit different conditions.
Student idea in the bad SE category (flexibility subdimension)	Flexibility assessment
"… to understand the chemistry concepts I am learning, I prefer to listen to the teacher's explanation or search for information online ..."	- The idea demonstrates only a single perspective. - No alternative solutions are provided for different learning conditions.

Table 10. Differences in students idea flexibility based on SE in problem context B

Thermochemistry topic problem (B)	
Student idea in the good SE category (flexibility subdimension)	Flexibility assessment
*"… I recall the concept of chemical bonding and **realize** that the heating process can be **maximized** by replacing the pan with a material that conducts heat well, such as **aluminum** … additionally, the system can be modified from an open system to a closed system, and the amount of fuel used can be increased …"*	- The idea incorporates multiple perspectives based on its functionality. - The students adapt their idea to suit different conditions.
Student idea in the bad SE category (flexibility subdimension)	Flexibility assessment
"… the combustion process in the stove can be improved by switching to a more modern fuel source, such as liquefied petroleum gas (LPG) ..."	- The idea demonstrates only a single perspective. - No alternative solutions are provided for different learning conditions

This result may serve as a reference for future studies on idea creativity, suggesting the consideration of students self-confidence, solid understanding of concepts, and learning experiences. Therefore, it is crucial for educators to build and support students SE, such as by providing positive feedback and creating a supportive learning environment (Vishnumolakala et al., 2017). In line with Alghamdi and Alanazi's (2020) study, the POGIL teaching method can emphasize the role of educators in creating a learning environment that encourages students to be active, critical, and creative within the context of chemistry education.

Interaction Between POGIL+FC and SE on Students CGI

Based on the explanation provided in RQ3, a positive interaction was observed between SE and the learning environment (the learning situation created by the POGIL+FC model) in relation to students CGI. A unique phenomenon occurred in the flexibility subdimension for students with bad SE. It was observed that the mean post-test score for the POGIL+FC group (3.4) was slightly lower than that of the PBL+FC group (3.8) (see **Figure 7**). This result contradicts Bandura (2002) theory, which suggests that individuals with good SE, when placed in a supportive environment, should achieve the desired outcomes. Factors such as cognitive flexibility could explain this phenomenon, where a cognitive process affects students ability to think of solutions in situations that they find challenging (Özen & Selçuk, 2022). For example, students who dislike certain subjects (e.g., chemistry) are less likely to feel challenged or motivated to complete tasks and activities (Huangfu et al., 2022; Huda & Rohaeti, 2023). This is consistent with the study by Puente-Díaz and Cavazos-Arroyo (2017), which indicates that SE has a positive relationship with creative thinking. SE interacts with the environment and the learning process to optimize cognitive processes, facilitating the creation of critical and creative ideas (Hsiao et al., 2023). In line with this, the study by Rodriguez et al. (2020) states that critical thinking questions in the POGIL teaching method will help students design and map out creative ideas in their minds. Although the statistical results obtained are relatively small (21.1%), the interaction between the learning environment created by the POGIL+FC teaching method and the varying levels of students SE can serve as a reference for future studies on idea creativity. This is in line with the research conducted by Mamombe et al. (2021), which suggests that the POGIL teaching method can foster motivation, interest, and diverse thinking among students when understanding chemistry topics.

The Relationship Between CGI and CP

Results of RQ4 have shown that there is a positive relationship between students CGI and the products they create. This positive correlation aligns with Rhodes' (1961) theory, which suggests that CP are the outcome of a collaboration between strong personal creativity, motivation, and an appropriate learning process (in this case, the POGIL+FC model). An appropriate learning process can motivate students to understand the core of the problem, generate ideas to solve it (Zhao & Wang,

Table 11. Relationship between creative ideas and the products generated by students

CGI thermochemistry topic

… to understand the concept of thermochemistry, I could create a scrapbook with the aim of organising the concepts clearly so that it is easy to carry around, such as in my school bag. The scrapbook would include relevant examples of the different types of systems in thermochemistry, such as ice melting …

CP thermochemistry topic

a

b

CGI chemical bonding topic

… for the chemical bonding topic, I will make a gift box. In addition to helping me remember the concepts, the box can be placed on my study desk or used as a creative display at school. On the box, I will include examples of each type of chemical bond …

CP chemical bonding topic

a

b

2022), and visualize these ideas in tangible forms. The analysis was conducted on the products produced, such as the initial idea generation (germinal), the accuracy of the chemistry concepts in the product, originality, and the usefulness of the product itself. For example, the germinal CP indicator measures the alignment of the product with the initial idea. The average rating for this aspect was at the medium level, indicating that the initial idea (CGI) was fairly aligned with the product created to solve the problem (Boonpracha, 2023). This is consistent with the study by Puchongprawet and Chantraukrit (2022), which posits that a CP should serve as a tool to help solve the problem at hand. Furthermore, a strong understanding of concepts is essential in generating CP to ensure that misconceptions are not introduced for the individual using the product (Pellegrino & Hilton, 2013). The positive relationship between CGI and CP in understanding chemistry concepts is depicted in **Table 11**.

The uniqueness or level of difference in the products generated by students meets the originality aspect, as it demonstrates a variation in the ideas and functions used to solve the problem (see **Figure 9**) (Puchongprawet & Chantraukrit, 2022). **Figure 9** illustrates the uniqueness or difference in the ideas behind the products designed to understand chemistry concepts, particularly the topics of thermochemistry and chemical bonding. These CP are the result of students visualization of their initial ideas, such as the ChemsGift Box, which helps students understand the topic of chemical bonding and can be used as a decorative piece on their study desk. The scrapbook allows students to easily carry their chemistry study materials to school. Furthermore, the magazine types also exhibit uniqueness, such as the pop-up magazine, which contains three-dimensional images related to chemistry topics, the scrap magazine, which showcases chemistry topics through paper folding art or origami, and the regular magazine, which presents

(a) Scrapbook, notebook, & ChemsGift Box (b) Pop up magazine

(c) Scrap magazine (d) Magazine

Figure 9. Students CP for understanding chemistry concepts (Source: Authors' own elaboration)

chemistry concepts in a simplified manner. Although the percentage of the positive correlation between CGI and CP generated by students is relatively large (45.97%), and the originality of these products is confined to the students problem context in learning chemistry and is temporary (Beghetto, 2021). Factors such as the time span for producing the product, students interest in learning, and problem solving skills present challenges for future studies to examine these factors. These elements will influence the efforts, ideas, and strategies students employ to solve the problems they encounter.

CONCLUSION

This study provides four key contributions to the field of creativity in idea generation by students in chemistry learning. First, the integration of POGIL+FC has been shown to influence variations in students CGI, particularly within the subdimensions of fluency and originality. Second, there are differences in CGI levels among students with varying SE, especially in the subdimensions of flexibility and originality. This highlights that SE influences the variation and perspective of ideas generated by students. Third, a positive interaction was found between the POGIL+FC teaching method and SE regarding differences in CGI. The learning environment and atmosphere created by POGIL+FC help enhance students confidence in using their knowledge to generate creative ideas. Fourth, a positive relationship was identified between CGI and the CP generated by students. Based on this, it is recommended that future research consider evaluating the quality of individual creative ideas prior to assessing broader aspects of creativity, such as CP.

Future studies on students creativity in the idea generation in chemistry education should focus on the MT subdimension. Researchers and educators should prioritize enhancing students conceptual understanding first, as a solid grasp of concepts will assist students in analyzing their ideas correctly, efficiently, and in an easily comprehensible manner. Additionally, learning environmental factors and students self-confidence should be explored in more depth to facilitate the generation of high quality ideas.

The implications of this research suggest that the POGIL+FC teaching method can serve as an alternative to enhance students CGI during chemistry lessons, regardless of their SE levels. This teaching method can be applied by chemistry teachers through careful preparation of lesson plans, such as outlining the activities to be conducted during both in-class and out-of-class phases, how to supervise the implementation of teaching during out-of-class sessions, and what activities should be carried out during the in-class sessions. Such a design can assist educators in effectively implementing POGIL+FC, particularly in the context of chemistry learning. A limitation of this study is that the relationship between CGI and CP is only based on the issues experienced by the students themselves, rather than on chemistry contextual problems. Future researchers could focus on the relationship between CGI and CP within the context of chemistry related problems. In order for the findings of this study (especially the relationship between CGI and CP) to be more accurately generalized to a broader population, an increase in the sample size that sufficiently represents the diversity of participants' characteristics is necessary. Additionally, a longer duration may be required to apply POGIL+FC so that students' CGI and CP can improve in a stable manner.

Author contributions: EFA: conceptualization, investigation, methodology, data curation, and writing–original draft; **IWD:** conceptualization, methodology, formal analysis, and writing–original draft; & **P & S:** conceptualization, methodology, and validation. All authors agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Ethical statement: The authors stated that the study was approved by the Research Ethics Committee at Universitas Negeri Malang on 27 October 2024 with approval number 03.10.3/UN32.14.2.8/LT/2024. Written informed consents were obtained from the participants.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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APPENDIX A: ASSESSMENT & RUBRIC GUIDELINES FOR CREATIVITY GENERATING IDEAS

Table A1. Assessment

No	Assessment aspect	Score			
		4	3	2	1
1	The student is able to present multiple ideas within a given timeframe.				
2	The ideas presented by the student in item number one are relevant to the problem context.				
3	The student describes ideas from various perspectives while maintaining relevance to the problem context.				
4	The students can maintain the core of their idea despite changes in certain conditions.				
5	The student proposes a unique and distinct idea with minimal similarity to others.				
6	The student suggests an idea that is beneficial for long-term problem-solving.				
7	The student provides empirical evidence to support the proposed idea.				
8	The students elaborate on their idea in great detail.				
9	The student explains the implementation plan for their idea.				
10	The student uses analogies to explain their idea, making it easier to understand.				

Note. Scale: 1: Bad; 2: Low; 3: Good; & 4: Excellent

Table A2. Rubric

Indicator	Assessment	Scoring criteria
Fluency		
1. Number of idea	Excellent	Students can present more than 9 ideas.
	Good	Students can present 7-9 ideas.
	Low	Students can present 4-6 ideas.
	Bad	Students can present fewer than 4 ideas.
2. Idea relevance	Excellent	Students can present more than 9 ideas that are relevant to the context of the problem.
	Good	Students can present 7-9 ideas that are relevant to the context of the problem.
	Low	Students can present 4-6 ideas that are relevant to the context of the problem.
	Bad	Students can present fewer than 4 ideas relevant to the context of the problem.
Flexibility		
3. Diversity	Excellent	Students can describe diverse ideas (more than 5 perspectives) that are relevant to the context of the problem.
	Good	Students can describe diverse ideas (4-5 perspectives) that are relevant to the context of the problem.
	Low	Students can describe diverse ideas (2-3 perspectives) that are relevant to the context of the problem.
	Bad	Students describe ideas from only one perspective relevant to the context of the problem.
4. Adaptability	Excellent	Students can modify and maintain the essence of their ideas to become more innovative when facing changes in situations and conditions.
	Good	Students can modify and maintain the essence of their ideas when facing changes in situations and conditions.
	Low	Students can modify and maintain the essence of their ideas, but only under certain conditions.
	Bad	Students are unable to modify and maintain the essence of their ideas when facing certain changes in situations and conditions.
Originality		
5. Novelty	Excellent	Students propose unique ideas that differ from others (similarity rate is only 10% of the total ideas).
	Good	Students propose fairly unique ideas (similarity rate is 11-30% of the total ideas).
	Low	Students propose ideas similar to others (similarity rate is 31-70% of the total ideas).
	Bad	Students propose ideas very similar to others (similarity rate is 71-100% of the total ideas).
6. Utility & problem-solving	Excellent	Students propose innovative ideas for solving problems, with the potential to be applied in similar future contexts.
	Good	Students propose ideas by describing the analysis of the current problem-solving situation.
	Low	Students propose ideas that do not fully address the core problem.
	Bad	Students propose ideas that are irrelevant to the existing problem.

Table A2 (Continued). Rubric

Indicator	Assessment	Scoring criteria
7. Scientific foundation	Excellent	Students propose ideas supported by empirical data widely recognized (e.g., books, news, articles).
	Good	Students propose ideas supported by data, but not widely recognized (e.g., social media news from anonymous sources).
	Low	Students propose ideas based on personal experience or opinion with unclear data sources.
	Bad	Students propose ideas solely based on personal experience or opinion without data or scientific evidence.
Elaboration		
8. Detail and complexity of ideas	Excellent	Students refine their ideas with very detailed explanations (including relevant evidence or examples, explanations for the examples used, and purpose of the ideas).
	Good	Students refine their ideas with fairly detailed explanations (including relevant evidence or examples and an explanation of the purpose of the ideas).
	Low	Students lack detail in refining their ideas (only including relevant evidence or examples).
	Bad	Students fail to refine their ideas (ideas are too simplistic).
9. Implementation	Excellent	Students detail the implementation plan clearly, including schedule, time needed, budget, team division, and strategies for addressing potential issues.
	Good	Students detail the implementation plan clearly, including schedule, time needed, budget, and team involved, but without considering strategies for potential issues.
	Low	Students do not detail their implementation plan.
	Bad	Students do not detail problem-solving ideas or their implementation plan.
Metaphorical thinking		
10. Metaphorical thinking	Excellent	Students use complex metaphors to analogize the relationships between multiple concepts (more than one concept).
	Good	Students use simple metaphors to analogize one concept.
	Low	Students use metaphors that create ambiguous meaning.
	Bad	Students do not use metaphors in their ideas.

APPENDIX B: ASSESSMENT & RUBRIC GUIDELINES FOR CREATIVE PRODUCT

Table B1. Assessment

No	Assessment aspect	Score 3	Score 2	Score 1
1	The produced product aligns with the initial design concept and the problem context.			
2	The produced product is unique and distinct from other products.			
3	The produced product introduces a new approach to understanding chemistry concepts and their relevance to daily life.			
4	The produced product is adequate in addressing students' needs to comprehend the relationship between chemistry concepts and their daily lives.			
5	The produced product is suitable for use in similar problem contexts.			
6	The produced product applies logical reasoning in accordance with scientific principles.			
7	The product produced is practical and easy to use.			
8	In addition to its primary function, the produced product offers various benefits.			
9	Students have developed a product with a conceptually accurate and aesthetically appealing design.			
10	The components of the produced product are well-integrated.			
11	The product incorporates solutions for complex problems.			
12	The produced product is simple and not excessive.			
13	The product presents a problem-solving approach that is easy to understand.			
14	The product exhibits high-quality components, construction, and detailing.			

Note. Scale: 1: Low; 2: Medium; & 3: Good

Table B2. Rubric

Indicator	Assessment	Scoring criteria
Dimension: Novelty		
1. Germinal	Good	The product aligns with the initial design idea and the context of the problem.
	Medium	The product differs from the initial design idea but still aligns with the context of the problem.
	Low	The product differs from the initial design idea and does not align with the context of the problem.
2. Originality	Excellent	The product is unique and distinct from other products, with comprehensive data presentation, including: 1) A chemistry concept and its contextual example 2) Explanation and description of the given example 3) A clear relationship between the concept and its contextual problem
	Good	The product is unique and distinct from others, with fairly comprehensive data presentation (*but missing one of the completeness criteria from the "Good" level*).
	Low	The product is simple and tends to be similar to other products.
3. Transformational	Excellent	The product introduces a new way to understand chemistry concepts and their relationship to students' daily lives over a certain period.
	Good	The product introduces a new way to understand chemistry concepts and their relationship to students' daily lives at that moment.
	Low	The product does not introduce a new way to understand chemistry concepts.
Dimension: Resolution		
4. Adequate	Good	The product meets students' needs in understanding the relationship between chemistry concepts and their daily lives.
	Medium	The product sufficiently meets students' needs in understanding the relationship between chemistry concepts and their daily lives (chemistry concept explanations are incomplete).
	Low	The product does not meet students' needs in understanding the relationship between chemistry concepts and their daily lives.
5. Appropriate	Good	The product is suitable for similar problem contexts.
	Medium	The product is only suitable for the current problem context.
	Low	The product is not suitable for the problem context..
6. Logical	Good	85-100% of the chemistry concepts in the product are correct.
	Medium	65-84% of the chemistry concepts in the product are correct.

Table B2 (Continued). Rubric

Indicator	Assessment	Scoring criteria
	Low	Less than 65% of the chemistry concepts in the product are correct .
7. Useful	Good	The product helps students solve problems (understanding and connecting chemistry concepts) quickly and practically.
	Medium	The product requires additional explanations for students to use it effectively.
	Low	The product is impractical for use..
8. Valuable	Good	Besides solving chemistry concept problems, the product also provides knowledge applicable to students' environments. Example: *Students choose to use a copper pan to ensure even and faster heating when cooking*.
	Medium	The product functions well in helping students understand chemistry concepts.
	Low	The product does not sufficiently help students connect chemistry concepts with real-world contexts.
Dimension: Elaboration and synthesis		
9. Attractive	Good	The product's design is highly engaging (in terms of color and images), capturing the audience's or users' attention.
	Medium	The product is fairly engaging (in terms of color and images), capturing some attention.
	Low	The product is not visually engaging.
10. Organic	Good	The product can be rearranged according to users' needs without compromising the harmony of components, aesthetics, functionality, or original design.
	Medium	The product is designed considering component harmony, aesthetics, and functionality.
	Low	The product lacks cohesion among its components, such as mismatched colors and inappropriate component choices.
11. Complex	Good	The product simplifies complex issues (concept comprehension, inter-concept relationships, real-world connections, and learning motivation) for students.
	Medium	The product partially simplifies complex issues but lacks effectiveness in some aspects.
	Low	The product does not simplify complex issues.
12. Elegant	Good	The product is simple and not excessive (all items have a clear function).
	Medium	The product is fairly simple but slightly excessive (some items lack a clear function).
	Low	The product is overly complex and excessive.
13. Expressive	Good	The product is presented in a communicative and easily understandable manner.
	Medium	The product is fairly communicative but requires additional explanations.
	Low	The product is not communicative and causes confusion.
14. Well-crafted	Good	The product has an appealing design, structured components, detailed elements, and uses economical or simple materials.
	Medium	The product has a fairly appealing design, somewhat structured components, limited detail, and uses economical materials.
	Low	The product lacks an appealing design and structured composition.