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Integration of AI into the CREATE Model to Foster Student Creativity in Molecular Geometry Learning Using TCOF Assessment and Williams' Indicators

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Abstract

The urgency of this study is to enhance students' creativity in molecular geometry learning by integrating AI into the CREATE model with TCOF assessment and Williams' creativity indicators. This study aims to analyze the implementation of the *CREATE (Connecting, Restructuring, Elaborating, Applying, Tasking, Evaluating)* learning model assisted by *Artificial Intelligence (AI),* as well as students' creativity levels at each stage of molecular geometry learning through the creation of molecular models using materials from the surrounding environment. This study employed a qualitative descriptive method with a sample of 20 twelfth-grade students divided into 5 groups. The implementation of the learning process was measured using the TCOF and LTT scales based on Williams' indicators, which include *fluency, flexibility, elaboration, originality*, and *evaluation*. The TCOF assessment results were categorized as "Very Adequate" across all stages: the "In-Class Activities that Encourage Creativity" and "Overall Learning Methods to Foster Creativity" categories scored 100%; the "Educator's Response to Students' Ideas" scored 97.66%; and the "Strate gy in Asking Questions" scored 95.33%. The achievement of creativity through LTT demonstrates a design capable of developing creativity in a structured, step-by-step manner. In individual assessments, *evaluation* reached 100% in all three stages (*Connecting, Restructuring, Tasking)*. The *Elaborating* stage achieved the highest individual scores on the indicators *of fluency* (88.75%), *flexibility* (87.50%), *elaboration* (91.25%), and *evaluation* (95%), all falling into the "highly creative" category. In the group assessment, the *Flexibility* indicator (100%) was achieved in all four stages; *Originality* was 90% in *the Applying* and *Tasking stages*; while *fluency* in the *Evaluating* stage (80%) was categorized as "creative." The results of this study indicate that the integration of the *CREATE* model with the assistance of *AI* technology can foster students' creativity in a gradual and structured manner.

Keywords: *CREATE Model, Student Creativity, Molecular Geometry, Artificial Intelligence (AI), TCOF, Williams' Indicators*

Introduction

The development of the Education Revolution 5.0 era demands a transformation in learning to cultivate 21st-century core skills, one of the key elements of which is creativity. Creativity is not merely about creating something new; it requires complex cognitive and affective processes, including the ability to generate many ideas (*fluency*), solve problems from various perspectives (flexibility), produce original ideas (originality), develop ideas in detail (elaboration), and be able to critically evaluate ideas (evaluation). Creativity in chemistry learning is a core issue that requires focus through structured learning that facilitates innovative learning models (Khumaeroh & Sumarni, 2020; Yuyut et al., 2025). However, the ability to learn chemistry often involves linking abstract concepts such as molecular geometry to real-world applications,

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reconstructing understanding from various perspectives, and developing ideas into meaningful tangible products (Orosz et al., 2023; Salame et al., 2022). Nevertheless, chemistry instruction in high schools still largely relies on conventional lecture methods; this approach hinders the development of students' creative thinking patterns, preventing them from creating innovative products (Khumaeroh & Sumarni, 2020; Handayani & Supardi, 2024).

This situation poses a challenge, compounded by the highly abstract and three-dimensional nature of molecular geometry. Students often struggle to visualize molecular shapes, understand the positions of lone pairs (LP) and their impact on bonds, and relate VSEPR theory to actual molecular structures. Various studies have demonstrated that project-based learning can significantly enhance students' creativity. Their research that creativity increased when project-based learning was implemented, with a 34% higher score compared to conventional teaching methods (Maharani et al., 2017). Creativity in chemistry learning improves significantly when integrated with digital technology, which has been proven to provide deeper motivation for exploring concepts (Sudiatmika et al., 2023). Meanwhile, to facilitate the implementation of learning observations specifically and structurally oriented toward the development of scientific creativity, the TCOF (*Teaching for Observation Form*) instrument specifically designed is utilized (Wahyu & Oktiani, 2025; Jannah et al., 2024).

The development of Artificial Intelligence (AI) technology presents new opportunities previously unavailable in education; AI is not only useful as a tool for generating information but can also function as a flexible learning partner, providing immediate feedback, and enabling more detailed exploration of ideas. A Previous research has shown that the integration of Artificial Intelligence (AI) into learning can enhance students' critical reflection through a responsive and personalized feedback system (Hwang & Chang, 2023; Amaliyah et al., 2025). This aligns with the findings of who noted that the use of AI in learning can have a tangible positive impact on students (Wang et al., 2025). Further emphasize that the combined use of AI with systematically structured instructional design can foster greater creativity compared to conventional learning (Kim et al., 2022). However, most existing research has focused on a single type of AI platform, while no study has yet explored four distinct AI platforms simultaneously within a single learning group (Ardyansyah et al., 2024).

There is a gap in the existing research: few studies have integrated chemistry learning models with AI technology and measured the development of students' creativity using two instruments simultaneously namely, the TCOF and the Williams instrument. One innovative learning model designed to address this gap is the *CREATE* learning model, which will be explicitly developed in this study across six stages with the assistance of AI-powered tools to support student creativity. Based on this background, the researcher has formulated two research questions: (1) How is the implementation of the *CREATE* learning model, supported by AI technology, in Molecular Geometry instruction assessed based on the TCOF evaluation? And (2) How are students' achievements of Williams' creativity indicators at each stage of the *CREATE model* in molecular geometry learning measured through Structured Worksheets (LTT)?.

Method

This study employs a descriptive approach with a case study design. This design was chosen to describe and interpret the development of students' creativity through the learning framework in detail, without manipulating variables. A case study design is applied when researchers wish to thoroughly understand complex phenomena within an objective context.

The data collected comprising TCOF observation scores and STS rubric assessments were analyzed descriptively in the form of percentages to reflect the extent to which the learning framework effectively fostered creativity. Data analysis was based on the model (Miles & Huberman, 1994). Which involves three stages: data reduction the selection of appropriate observational data and assessments; data presentation in the form of narratives, tables, and comparisons across stages; and drawing conclusions based on the aspects of creativity targeted in each stage of *the CREATE model.*

The participants in this study consisted of 20 12th-grade high school students in Indonesia who were selected using purposive sampling based on the following criteria: the students had studied the prerequisite material (chemical bonding and Lewis structures) and were willing to participate in the entire learning sequence over three sessions. The students were divided into 5 groups (K1–K5), each group consisting of 4 students with different learning styles: Visual (V), Auditory (A), Audiovisual (AV), and Kinesthetic (K). Group assignments were determined using a learning style questionnaire adapted from the VARK framework (Flemings & Mills, 1992), with a slight modification to the Audiovisual category to align with 21st-century multimedia-based learning. Each student in a group used a different AI platform: Claude AI, ChatGPT, Gemini AI, and Perplexity AI. The use of these diverse AI tools aimed to enrich information and encourage the exchange of viewpoints among group members from various perspectives.

The implementation of learning through the *CREATE* learning model consists of six sequential stages: *Connecting* (linking concepts to real-world phenomena), *Restructuring* (restructuring understanding), *Elaborating* (elaborating on understanding), *Applying* (applying concepts to create molecular models), *Tasking* (working on project tasks), and *Evaluating* (evaluating learning outcomes).

The instruments used by the researchers were: (1) the TCOF, which consisted of 20 observation samples to measure the implementation of each stage of *the CREATE model* by the observer, (2) a creativity rubric based on indicators, which includes five aspects of creativity: *Fluency, Flexibility, Originality, Elaboration*, and *Evaluation*, (3) and the Structured Task Sheet (LTT) as a structured guide for the proper implementation of multiple creative works.

Results

Implementation of the AI-Assisted CREATE Model (TCOF)

The TCOF assessment was conducted by two observers at each stage of the *CREATE process*. The assessment results confirmed that the model was implemented at the "very good" level.

Table 1. *TCOF Assessment Results by CREATE Stage*

TCOF Category	Observer 1 Score	Observer 2 Score	Score Calculation (%)	Category
Question-Asking Strategy	2.87	2.85	95.33%	Highly Appropriate
Teachers' Responses to Students' Ideas	2.93	2.93	97.66%	Highly Appropriate
Classroom activities that encourage creativity	3.00	3.00	100%	Highly Recommended
Overall teaching methods to foster creativity	3.0	3.00	100%	Highly Appropriate

Based on Table 1, all TCOF categories fall into the "Highly Recommended" category. The categories "In-class activities that foster creativity" and "Overall learning methods to foster creativity" received a perfect score of 100%, indicating that the AI-assisted *CREATE* learning activity concept has fully fostered students' creativity. In the "Strategies for Asking Questions" category, the score was 95.33%, the lowest TCOF category, because at several stages, one aspect of fostering comparison through AI results had not been optimally achieved. The TCOF assessment across all categories used a 1–3 scale, indicating that the AI-assisted *CREATE* model has been successfully implemented as a learning approach that fosters students' creativity.

Achievement of Williams' Creativity Indicators: Individual Assessment by CREATE Stage (LTT)

Individual assessment via LTT was applied to all stages of *the CREATE model* to evaluate the achievement of Williams' creativity indicators on an individual basis. The results are shown in Table 2.

Table 2. *Results of the Williams Creativity Indicator Assessment: Individual Assessment by CREATE Stage*

CREATE Stages	Williams Indicators	Assessment	Average (%)	Category
Connecting	Fluency	Individual	85%	Very Creative
	Evaluation	Individual	100%	Very Creative
Restructuring	Fluency	Individual	85%	Very Creative
	Elaboration	Individual	90%	Very Creative
	Evaluation	Individual	100%	Very Creative
Elaboration	Fluency	Individual	88.7%	Very Creative
	Flexibility	Individual	87.5%	Very Creative
	Elaboration	Individual	91.25%	Very Creative
	Evaluation	Individual	95%	Very Creative
Applying	Flexibility	Individual	97.5%	Very Creative
	Elaboration	Individual	85.25%	Very Creative
	Evaluation	Individual	95%	Very Creative
Tasking	Evaluation	Individual	100%	Very Creative
Evaluation	Evaluation	Individual	88.75%	Very Creative

Based on Table 2, the *evaluation* indicators consistently achieved the highest score of 100% in the Connecting, Restructuring, and Tasking stages. The Elaborating stage achieved the most comprehensive individual results with four indicators active simultaneously: Fluency 88.75%, Flexibility 87.50%, Elaboration 91.25%, and Evaluation 95%, with an overall category of "highly creative." In the Applying stage, the individual's Flexibility score reached 97.50%, which was the highest individual score compared to all indicators and stages.

Achievements of the Williams Creativity Indicators: Group Assessment by *CREATE* Stages (LTT)

Group assessment measures specific achievements of each group (K1–K5) in completing a collaborative creative project. The results of the group assessment are shown in Table 3

Table 3. *Results of the Williams Creativity Indicator Group Assessment by CREATE*

CREATE Stages	Williams Indicators	Assessment	Average (%)	Category
Connecting	*Flexibility*	Group	100%	Very Creative
Restructuring	*Flexibility*	Group	100%	Very Creative
Elaborating	*Flexibility*	Group	100%	Very Creative
Applying	*Flexibility*	Group	90%	Very Creative
	Originality	Group	90%	Very Creative
Tasking	*Originality*	Group	90%	Very Creative
	Elaboration	Group	85%	Very Creative
	Flexibility	Group	100%	Very Creative
Evaluating	*Fluency*	Group	80%	Creative

Based on Table 3, the *flexibility* indicator in this group consistently achieved a maximum score of 100% across all four stages*: Connecting, Restructuring, Elaborating, and Tasking*. The *"Originality"* indicator in the *"Applying"* and *"Tasking"* stages scored 90%, reflecting the group's success in selecting original materials from their surroundings. The only indicator with the lowest score though still categorized as "creative" was the group's "*Fluency"* in the *"Evaluating"* stage, which scored 80%

Discussion

Implementation of the AI-Assisted CREATE Model Through TCOF

TCOF measurement results using a 1–3 scale showed that the implementation of the entire TCOF fell into the "Very Feasible" category, proving that the AI-assisted *CREATE* model had been implemented coherently and in a structured manner throughout all stages of Molecular Geometry learning. A maximum score of 100% was achieved in the two categories "In-class activities that encourage creativity" and "Overall learning methods to foster creativity," both of which received a perfect score of 100%. This indicates that the AI-assisted *CREATE* learning activities have effectively facilitated the learning stages in a creative manner. In line with the research it was found that digital technology-based learning that is structured and systematic in its stages can significantly improve the quality of the learning process (Sudiatmika et al., 2023). The overall learning method, with a score of 100%, indicates that the project-based learning approach integrated into the *CREATE* model has proven to be a method that can foster students' creativity (Yusup et al., 2022).

The "Strategies for Asking Questions" category received a score of 95.33%, the lowest among all categories. Based on the observation data ( ), a contributing factor lies in the aspect of "educators encouraging comparison of results through AI," which, in the *Applying* stage, received a score of 2 out of 3 from both observers. This implies that the application of AI functions as a learning aid and for confirming student responses has not been fully utilized across all stages of the learning process by the students. This can be understood as an adaptation from the "Connecting" stage, the first stage requiring a deeper understanding by linking AI to learning. Similarly, in the "Applying" stage, students prioritized the technical aspects of constructing molecular models over confirming their answers through AI. This finding implies that more in-depth and consistent guidance is required from the early stages to optimize the use of AI as a tool for scientifically validating responses.

However, the category "Educators' Responses to Students' Ideas" scored 97.66%, indicating that educators consistently expressed appreciation and encouragement for students' creative ideas throughout all stages of learning. Teachers' responses to students' ideas are one of the most crucial aspects of learning that foster the development of creativity, as positive feedback from educators creates a psychologically safe environment and encourages students to express their ideas with confidence in the outcomes they achieve even if those ideas are incorrect. This environment is essential in molecular geometry instruction to produce molecular models using original materials from the surrounding environment; thus, teachers' support which values students' decisions regarding material selection is key to fostering creative success.

Achievement of Williams' Creativity Indicators in Individual LTT Assessments by CREATE Stage

In the individual assessment based on Table 2 of the LTT evaluation, different patterns of creativity were observed at each stage of the *CREATE framework.* In the *Connecting* stage, students were assessed using two indicators: *Fluency*, with a score of 85% in the "very high" category for depicting the 3D molecular structure of H_2O based on their diverse understandings, and *Evaluation,* with a score of 100% in the "very creative" category for confirming their initial answers with the help of AI technology. AI that has been well-designed for the learning context directly functions to process responses that encourage critical reflective thinking, and this study supports that statement in the context of high school chemistry learning (Hwang & Chang, 2023).

In the *Restructuring* Stage*,* performance was assessed using three active indicators: *Fluency* (85%) in identifying five simple molecules along with their AXE notation and bond angles; *Elaboration* (90%) in explaining the differences in the H-O-H (104.5°), H-N-H (107°), and H-C-H (109.5°) in a scientific manner that relates the concepts of PEB and electron repulsion, and *Evaluation* (100%), which again achieved the maximum score. At this stage, the 90% *Elaboration* score indicates that the process of restructuring understanding through group discussion yielded results, demonstrating the ability to elaborate on more complex concepts. The four AI platforms, each providing different responses within a single group, encouraged the exchange of perspectives to analyze various explanations and arrive at a more comprehensive understanding.

The *Elaborating* stage achieved the highest and most varied individual scores, with four active indicators: *fluency* at 88.75%, *flexibility* at 87.50%, *elaboration* at 91.25%, and *evaluation* at 95% overall, categorized as "highly creative." At this stage, students analyzed complex molecules (PCl_5, SF_6, XeF_2, IF_5, SO_2) based on their diverse understandings and explained why XeF_2 remains linear despite having three lone pairs of electrons (LPE). The use of AI as an exploratory response aid at this stage allows students to utilize this technology to independently explain concepts from various sources, which directly demonstrates its ability to encourage greater elaboration (Maharani et al., 2022).

In the *"Applying"* stage, there were two active indicators: *flexibility* (97.50%) in designing a molecular model by considering four aspects simultaneously namely, AXE notation, bond angles, construction materials, and polar/nonpolar properties. This achievement indicates that when students are given project-based tasks such as creating 3D molecular models using materials from their surroundings it directly encourages them to think from multiple perspectives, demonstrating high cognitive flexibility. At this stage, the elaboration indicator reached 86.25% in the "Very Creative" category, proving the students' ability to refine their design tables with 3D sketches, PEB positions, bond angles, and detailed material selection. The *evaluation* indicator (95%), which involved predicting challenges and solutions encountered during molecular model creation and confirming them with AI assistance, demonstrated a high capacity for prediction and evaluation.

In the *Tasking* phase*,* the evaluation indicator again achieved 100% because all students were able to evaluate the model-building procedures by comparing them with the explanations provided by individual AI sources a phase that functions most effectively as creative scaffolding and used this to evaluate and refine the procedures they designed in detail on an individual basis. That students' active engagement with AI rather than merely being passive users is the primary focus of AI in fostering creativity (Wang et al., 2025).

In the evaluation stage, the evaluation indicator scored 88.5%, which was lower than in the previous stage, as students refined their overall understanding of the learning material by confirming their explanations with the help of AI. This indicates that some students were not yet fully capable of applying all the concepts they had learned to more complex conclusions, a challenge also related to time constraints.

When viewed as a whole, the individual competency indicators show that the "evaluation" indicator demonstrated the highest proficiency among students across all stages, while the "fluency" and "flexibility" indicators varied more widely, adapting to the characteristics of the tasks at each stage. This proves that the AI-assisted *CREATE* model is particularly effective in developing students' evaluative skills through the comparison of information provided by AI. The explicit integration of AI into learning as an evaluation tool results in significantly greater development of creative thinking compared to conventional instruction based tasks (Suyono et al., 2025). This finding reinforces research on the use of AI as an evaluative tool that not only provides answers but also fosters a more developed mindset in students, enabling them to actively compare, critique, and refine their understanding at every stage of learning.

Achievement of Williams' Creativity Indicators in LTT group assessments by the CREATE stages

In the group assessment (Table 2), the *Flexibility* indicator consistently reached 100% across all four stages (*Connecting, Restructuring, Elaborating,* and *Tasking*), demonstrating that, overall, the group successfully refined their thinking by fully incorporating diverse perspectives from fellow members. The 100% consistency in the Flexibility indicator across the four stages demonstrates that grouping students with different learning styles and using an AI platform fosters more productive and idea-rich discussion interactions. Each group member brings a unique perspective, which directly fosters group flexibility (Kim et al., 2022).

The *Originality* indicator in the *Applying* (90%) and *Tasking* (90%) stages showed that students were able to demonstrate the group's effectiveness in selecting materials that met three criteria simultaneously: materials that had not been widely used or considered by others, materials sourced from the surrounding environment, and the creation of visualizations highlighting differences in atomic size. Achieving a 90% score on the originality indicator is the most challenging to implement in fostering creativity, as its very nature requires producing something new and distinct from what has existed previously. In the tasking stage, the indicators included originality (90%) and flexibility (100%); the elaboration indicator scored 85%, falling into the "highly creative" category for accurately determining molecular models in terms of precise 3D shapes, bond angles close to theoretical values, PEB characterized by distinct materials, and strong, proportional structures. Taken together, these active indicators make this product the most in-depth activity for fostering overall group creativity.

The *fluency* indicator was one of the lowest categories in the *evaluating* stage (80%) within the "creative" category, when the group presented and answered questions from the audience regarding the understanding they had developed. This suggests that their understanding was likely quite good, and they demonstrated the ability to communicate in an organized and fluent manner in public; however, they require more in-depth guidance. Due to time constraints, the evaluation stage did not receive sufficient time to develop a systematically organized presentation. Fluency in conveying an idea to others requires dedicated practice in structured communication, which demands time and in-depth, well developed guidance in understanding (Noer, 2021). This finding may suggest that future researchers allocate a more proportionate amount of time to the evaluation stage.

Overall, the level of creativity achieved by both individual and group participants showed consistent development throughout the *CREATE* stages*,* beginning with the *Connecting* stage which successfully elicited initial ideas through to the evaluation and presentation of work in the *Evaluating* stage. This aspect demonstrates that the AI-assisted *CREATE* model successfully fosters students' creativity in a gradual and structured manner, in line with the *scaffolding* principle in constructivist learning theory (Sudiatmika et al., 2023). The use of four different AI platforms within a single group has proven successful in creating a discussion space rich in information and elaboration across nearly all stages. That learning designed to simultaneously enhance creativity at both the individual and group levels successfully achieved a deeper level of creativity (Ikhwanuddin et al., 2021). This finding has a strong influence on the implementation of the AI-assisted *CREATE* model with abstract chemistry material that requires multi-perspective exploration.

Conclusion

This study concludes with two main findings. First, the implementation of the AI-assisted *CREATE* learning model, as assessed using the TCOF scale, was rated "Very Appropriate" across all evaluation stages on a scale of 1–3. In the categories of "In-Class Activities that Foster Creativity" and "Overall Learning Methods to Foster Creativity," a perfect score of 100% was achieved; "Educator Responses to Students' Ideas" scored 97.66%; and "Strategies for Asking Questions" scored 95.33%. Second, creativity achievement was measured using Williams' indicators in the LTT. In individual assessments, *the "Evaluation"* indicator achieved a perfect score of 100% across all three stages (*Connecting, Restructuring, Tasking),* demonstrating its effectiveness in fostering students' self-reflection. The *Elaborating* stage achieved the highest and most varied individual scores, with four active indicators: *fluency* at 88.75%, *flexibility* at 87.50%, *elaboration* at 91.25%, and *evaluation* at 95% all falling into the "highly creative" category. In the group assessment, the *Flexibility* indicator reached 100% across all four stages; *Originality* reached 90% in *the Applying* and *Tasking* stages; while *Fluency* in the *Evaluating* stage (80%) was one of the "creative" categories with a lower score, indicating that presentation skills require further guidance. Overall, the integration of the *CREATE* model with the aid of AI technology proved highly effective in fostering students' creativity in learning molecular geometry in a gradual, thorough, and structured manner.

This study has a limitation in that the allocation of learning time was not optimal, so some stages of *the CREATE model* could not be fully explored by the students. This is evident from the group's *fluency* indicator achievement in the *"evaluating"* stage, which fell into the "creative" category (80%). Additionally, the use of AI platforms was not limited to a single platform but facilitated the use of four different AI platforms by each group member; this creates an opportunity for future research not explored in this study, namely a comparison of creative performance assessments based on the AI platforms applied. For future research, it is recommended to extend the learning time allocation for each stage of the *CREATE* learning process so that it can be implemented optimally, and to expand the research sample to include more schools in order to strengthen the findings.

Acknowledgment

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