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Guardrails Approach For Digital Learners' Scientific Creativity And Innovation

Joyce T. Crisologo[a]*, Elisa N. Chua, Ph.D[b]

[a] *official email address*: *joyce.crisologo@deped.gov.ph*
[a] *Teacher I, Sto. Tomas City National High School-Sto. Tomas City, Philippines*
[b]*Professor I, Laguna State Polytechnic University-San Pablo City Campus, Philippines*

Abstract

This paper examined the effectiveness of the Guardrails Approach in improving the scientific creativity and innovation of Grade 7 learners in an AI-assisted learning environment. Built around the challenge of equipping students with essential skills for the 21st century amid continuing problems associated with a lack of critical thinking and rote memorization in science education, the study applied the strategies of Socratic Prompting Approach and Tiered Assistance Approach. In this study, two (2) sections with forty-six (46) and forty-three (43) Grade 7 students of Sto. Tomas City National High School participated in a post-test-only experiment that compared the two instructional strategies. Each group covered the same fourth quarter lessons in science using AI tool specifically ChatGPT. Both groups were taught using one of the two approaches. The scientific creativity and innovativeness were measured based on six criteria – fluency, flexibility, originality, elaboration, problem-solving, and approach diversity. Results indicated that both strategies helped contribute to the development of creativity and innovation among students. The use of Socratic questioning proved highly efficient in stimulating higher order thinking skills including originality and reasoning. At the same time, tiered assistance was found to assist learners in acquiring fluency in problem solving. Moreover, it can be stated that the Guardrails Approach represents an effective strategy for using AI technology in science instruction in accordance with the requirements of the modern-day learner.

Keywords: AI-assisted learning, Guardrails Approach, Innovation Skills, Post-test-only design, Scientific creativity

1. Introduction

Recent global education agendas such as UNESCO's Futures of Education (2023) and the OECD Learning Compass 2030 emphasize creativity, innovation, and problem-solving as key 21st-century skills. Similarly, the Philippines' K to 12 program emphasizes the placement of Career and Life Skills and Learning and Innovation Skills, under which scientific creativity and innovation are focal developmental outcomes (Department of Education [DepEd], 2023). Such competencies are not only necessary in scientific learning but also in addressing complex, real-life problems such as climate change and natural disasters. The rising frequency of volcanic eruption, earthquakes, and other ecological catastrophes in the Philippines highlights the imperative for preparing students who can think critically and creatively about scientific occurrences. However, the majority of students display repetitive learning without genuine understanding, memorizing textbook definitions rather than using knowledge in a novel context or generating creative solutions (PISA, 2023). Despite the emphasis of the curriculum on higher-order thinking, a majority of Filipino students still score below the proficiency levels in scientific thinking and creativity. As was shown by the findings of the

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Program for International Student Assessment (PISA, 2023), most of the students could not apply scientific concepts to novel situations or coming up with creative explanations regarding everyday occurrences. The same goes for the study by Ballesteros and Tarrayo (2024) that suggests that science lessons at the secondary level of education tend to be content driven without any scope of exploration or experimentations. As a result, students learn about volcanoes but are unaware of the mechanics behind them and their applications in various aspects of human life and nature. Such an approach stifles the creativity in science. Another factor that does not encourage innovation, according to Sawyer (2018), lies in traditional classroom habits that lack individuality and scaffolding. Generally speaking, students find it difficult to acquire the courage necessary to explore different ideas, test them, and improve them incrementally. The introduction of artificial intelligence in education, although promising, also presents another pedagogical challenge in terms of how to teach students to use AI as a learning tool rather than just a means of cheating. The reason behind this difficulty lies in the absence of well-defined AI pedagogies.

The proposed pedagogical intervention for filling the identified gap is Guardrails approaches for the development of scientific creativity and innovation among Grade 7 Science learners. "Guardrails" refer to human-supported scaffolding integrated into AI-assisted learning, where technology supports the student’s cognitive processes without supplanting them entirely. The Guardrails approaches utilize two complementary strategies:

Socratic Prompting Strategy, which involves the student in systematic inquiry during the Exploration, Connection, and Application phases; and Tiered Assistance Strategy, which entails step-by-step support from Hint, Prompt, and Model stages. The Guardrails approaches leverage AI-assisted tutoring as an interactive process in which the student plays an active role in hypothesis formation, explanation seeking, and problem solving. Thus, AI serves as a cognitive assistant that fosters the learner’s ability to think with curiosity, divergently, and scientifically. Scientific creativity and innovation in this research will be tested in terms of six distinct variables: fluency, flexibility, originality, elaboration, problem solving, and diversity of approach. Through integrating these variables into AI-driven exploration of volcanic eruptions a complex phenomenon in its own right this research provides a practical setting for measuring creative scientific cognition. From a theoretical perspective, this paper extends debates on AI-assisted education by exploring the potentiality of guardrail-based AI tutoring for fostering creative reasoning rather than automating content delivery. This paper integrates the concepts derived from Socratic pedagogy, scaffolding theory, and the literature on the use of AI in education (Graesser et al., 2001; VanLehn, 2006; Chowdhury et al., 2024) and explains how AI technologies can be used to elicit curiosity, creativity, and metacognition in students. Further, the current work responds to the latest call by UNESCO (2024) for an ethical examination of AI implementation in learning settings. In terms of practical implications, the study holds policymakers and educators accountable for making AI education effective. On the one hand, this study provides teachers with empirically-supported evidence that enables them to restructure their science lessons using AI tools for moving from content rote to novel inquiry through AI-assisted dialogue. Socratic prompting can stimulate students' questioning and conceptual understanding, and scaffolded instructions will foster inclusion by providing support depending on the individual needs of each participant. On the other hand, the findings are compatible with the DepEd's MATATAG Curriculum (2023). Apart from academic significance, this research is also important in building the resilience of a nation against any disasters in the sense that it aims at building a generation of scientifically innovative learners who will be able to convert scientific information into community-based innovations. Through the incorporation of scientific imagination and innovation on such subjects as volcanic eruptions, apart from instilling scientific explanation of natural occurrences, scientific creativity in finding environmentally friendly and sustainable ways of using the energy released by the volcano while enhancing human security becomes paramount.

2. Review of Related Literature

2.1 Artificial Intelligence in Education

Artificial intelligence (AI) has become increasingly visible in education because of its potential to improve teaching and learning experiences. In recent years, researchers have explored how AI can support personalized learning, adaptive instruction, intelligent tutoring systems, and automated feedback in classrooms (Baidoo-Anu & Owusu Ansah, 2023; Zhai et al., 2021). As schools continue to adopt learner-centered approaches, AI technologies are being recognized not only as instructional tools but also as learning supports that can help students become more engaged and active participants in the learning process.

One of the most common applications of AI in education is personalized learning. AI-powered systems can analyze students' learning progress, strengths, and areas of difficulty in order to provide instruction that matches individual needs. Studies have shown that personalized learning environments may improve learners' motivation, engagement, and confidence because students are allowed to learn at their own pace and receive support suited to their abilities (Johnson & Smith, 2019). Similarly, intelligent tutoring systems (ITS) use adaptive feedback and natural language interaction to guide students during learning activities. Research suggests that these systems can improve conceptual understanding, participation, and problem-solving skills among learners (Rolland et al., 2018).

AI has also been widely used in adaptive assessments and automated feedback systems. Adaptive assessments adjust the difficulty level of tasks according to learners' real-time performance, allowing students to receive challenges appropriate to their level of understanding. Research indicates that this type of assessment may improve learning outcomes and lessen learner anxiety because students receive immediate feedback and targeted support (Lee & Wu, 2019; Chen et al., 2020). In addition, automated grading and AI-assisted feedback systems help teachers manage assessment tasks more efficiently while providing students with timely responses that support learning improvement (Li et al., 2021).

Despite these advantages, concerns regarding the use of AI in education continue to emerge. Although generative AI tools such as "ChatGPT" can provide explanations, feedback, and academic assistance, excessive dependence on AI-generated responses may limit opportunities for independent thinking and reflective learning. Without proper instructional guidance, students may rely on AI mainly for obtaining answers rather than for developing deeper conceptual understanding and problem-solving skills. These concerns highlight the need for structured pedagogical approaches that encourage meaningful cognitive engagement while ensuring responsible and ethical use of AI in education.

2.2 Guardrails Approach in AI-Assisted Learning

Recent studies suggest that AI-assisted learning environments become more effective when supported by structured instructional guidance or "guardrails." In educational settings, guardrails refer to scaffolded supports and constraints that guide learners' thinking processes while still allowing opportunities for inquiry, exploration, and independent reasoning. Rather than replacing students' thinking, guardrails help learners engage productively with AI systems through guided questioning, reflective reasoning, and scaffolded problem solving.

Research on scaffolding and inquiry-based instruction has consistently shown that structured support contributes to learners' conceptual understanding, inquiry engagement, and creative performance. Studies by Ernawati et al. (2023) revealed that scaffolded learning environments improved students' fluency, flexibility, originality, and persistence in solving complex tasks. These findings suggest that creativity develops more effectively when learners receive enough guidance to manage cognitive challenges while still maintaining opportunities for independent exploration.

The emergence of large language models and AI tutoring systems has further expanded the possibilities of AI-assisted instruction. Unlike traditional rule-based tutoring systems, modern AI tools can engage learners in adaptive questioning, natural language dialogue, and personalized feedback. However, researchers have emphasized that AI systems must be carefully designed to avoid overdependence and superficial learning (Chowdhury et al., 2024). In response, recent studies have proposed the integration of pedagogical guardrails into AI tutoring systems to ensure that learners remain cognitively engaged throughout the learning process.

Guardrail-based AI systems encourage learners to justify their reasoning, analyze information, and construct solutions rather than simply receive direct answers. These approaches are grounded in constructivist and sociocultural learning theories, particularly Vygotsky's concept of scaffolding and the Zone of Proximal Development, which emphasize the importance of guided support in helping learners achieve higher levels of understanding. Empirical studies further suggest that guardrail-based AI tutoring may improve learner engagement, reduce cognitive load, and strengthen conceptual understanding in science and STEM education (Wang et al., 2024; Becker et al., 2025).

Within guardrail-based instruction, two strategies have become particularly relevant in supporting higher-order thinking and creativity: the Socratic Prompting Strategy and the Tiered Assistance Strategy. ---

2.3 Conceptual Framework

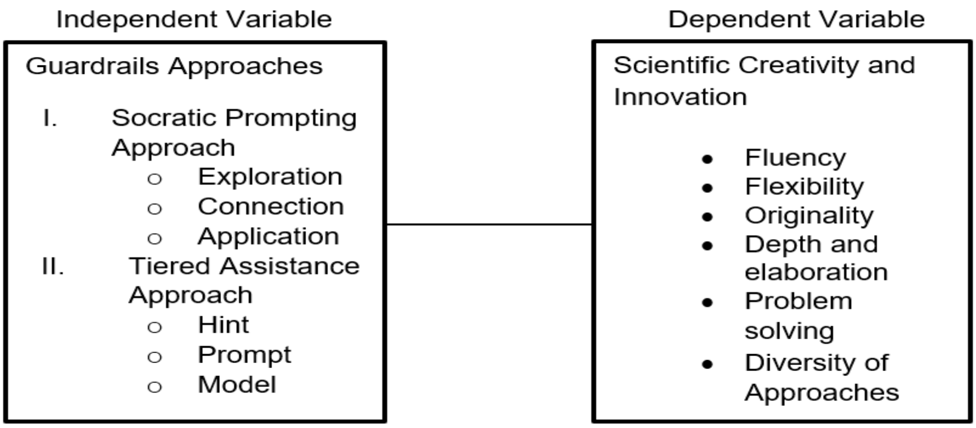

Figure 1. Research Paradigm

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3. Hypotheses

The study tested the following null hypotheses:

There are no significant differences in the Scientific Creativity and Innovation Performance Formative Assessment scores of the of the Grade 7 respondents across the stages of Socratic prompting

There are no significant differences in the Scientific Creativity and Innovation performance formative assessment scores of the respondents in the Guardrails approaches of the Grade 7 students when categorized according to the highest levels of Tiered assistance approaches required to complete the task.

There are no significant differences between the Scientific Creativity and Innovation performance post assessment scores of the two groups of respondents exposed to the Guardrails approaches.

4. Methodology

This study used a two-group post-test–only comparative research design to examine the effects of two instructional approaches: Socratic Prompting and Tiered Assistance. According to USQ (2022), such experimental designs are robust in minimizing threats from testing and maturation effects, while Pressbooks UTA highlights that post-test–only models can establish causality when groups are comparable and exposed to the same conditions except for the intervention. Guardrails-based instructional strategies were implemented in both groups, with Socratic Prompting serving as a structured inquiry approach and Tiered Assistance as an adaptive scaffolding approach.

5. Results and Discussion

Table 1-1
Scientific Creativity and Innovation Performance Formative Assessment Scores of Socratic Prompting Approach Group

Scientific Creativity and Innovation Skills	Exploration			Connection			Application			Overall Mean Score		Remarks
	Mean	SD	VI	Mean	SD	VI	Mean	SD	VI	Mean	SD	
Fluency	2.27	0.343	D	2.79	0.347	D	3.03	0.295	P	2.70	0.33	Satisfactory
Flexibility	2.11	0.209	D	2.86	0.172	D	2.48	0.235	D	2.48	0.21	Satisfactory
Originality	2.07	0.363	D	2.61	0.446	D	1.95	0.217	D	2.21	0.34	Satisfactory
Depth and Elaboration	2.29	0.335	D	2.70	0.325	D	2.97	0.113	D	2.65	0.26	Satisfactory
Problem-Solving	2.15	0.291	D	2.52	0.271	D	2.90	0.201	D	2.52	0.25	Satisfactory
Diversity of Approaches	2.20	0.229	D	2.75	0.230	D	2.65	0.201	D	2.53	0.22	Satisfactory

Legend:4.0-3.5 Outstanding/Excellent(E); 3.49-3.0 Very Satisfactory/Proficient(P); 2.99-2.01 Satisfactory/Developing(D); 1.99 -1.00 Fairly Satisfactory/Beginning(B); Source: DO 8 s. 2015)

Table 1-1 presents the Scientific Creativity and Innovation Performance Formative Assessment Scores of Grade 7 students exposed to the Socratic Prompting Approach across six dimensions: fluency, flexibility, originality, depth and elaboration, problem-solving, and diversity of approaches during the exploration, connection, and application stages. Overall, results were interpreted as "Satisfactory," with mean scores ranging from 2.01 to 3.00. Among these, fluency (M = 2.70, SD = .33) and depth and elaboration (M = 2.65, SD = .26) obtained the highest means, indicating that students were most capable of generating ideas and explaining them in detail. In contrast, originality (M = 2.21, SD = .34) and flexibility (M = 2.48, SD = .21) were the lowest, though still satisfactory. The application stage also showed higher performance compared to exploration and connection, with relatively small standard deviations indicating consistent student performance. These results suggest that the Socratic Prompting Approach provided a structured learning process that supported students in developing scientific creativity and innovation, particularly in generating ideas and elaborating explanations. Through guided questioning, students were encouraged to explain, justify, and apply scientific concepts to real-life situations such as disaster preparedness and evacuation planning. Performance was strongest in tasks requiring application, where students could transfer knowledge to practical contexts. Across stages, students demonstrated different aspects of creative performance: exploration supported idea generation and fluency, connection developed their ability to relate concepts and deepen explanations, and application enabled them to design solutions and engage in problem-solving tasks. However, despite these strengths, originality and flexibility remained comparatively low, suggesting that many students relied on familiar or AI-influenced responses rather than producing highly novel or diverse ideas. Transcript analysis confirmed that some learners depended heavily on AI-generated suggestions, limiting divergent thinking, although Socratic questioning still helped improve explanation and reasoning.

A classroom scenario on earthquake evacuation planning illustrated these findings, where students responded well to guided questions and produced detailed, practical ideas but often repeated similar solutions such as emergency kits and safety protocols. These findings align with Santos-Guevara et al. (2026), who found that AI-assisted Socratic discussion enhances engagement and reflective learning, and Fakour and Imani (2025), who reported that such approaches promote critical thinking through structured questioning.

The results are also consistent with Constructivist Learning Theory (Piaget), which emphasizes learning through active engagement and reflection, and Vygotsky's Zone of Proximal Development, which highlights the role of scaffolding in developing independent reasoning. Furthermore, Hu et al. (2025) and Chowdhury et al. (2024) support the idea that AI-assisted Socratic questioning strengthens higher-order thinking skills, while Kapoor et al. (2025) explain the lower originality scores as a result of limited opportunities for divergent thinking and over-reliance on AI-generated responses.

Table 1-2

Scientific Creativity and Innovation Performance Formative Assessment Scores of Tiered Assistance Approach Group

Scientific Creativity and Innovation Skills	Mean	SD	Verbal Interpretation	Remarks
Fluency	3.09	0.313	Proficient	Very Satisfactory
Flexibility	2.44	0.245	Developing	Satisfactory
Originality	2.52	0.162	Developing	Satisfactory
Depth and Elaboration	2.81	0.195	Developing	Satisfactory
Problem-Solving	2.76	0.215	Developing	Satisfactory
Diversity of Approaches	2.80	0.233	Developing	Satisfactory
Overall Mean Score	2.74	0.23	Developing	Satisfactory

Legend:4.0-3.5 Outstanding/Excellent; 3.49-3.0 Very Satisfactory/Proficient; 2.99-2.01 Satisfactory/Developing; 1.99 -1.00 Fairly Satisfactory/Beginning

Table 1-2 presents the Formative Assessment Scores of Grade 7 students exposed to the Tiered Assistance Approach, where ChatGPT functioned as a scaffolded support tool providing varying levels of assistance (hints, prompts, and modeling) based on learner needs. Students were assessed across six dimensions of scientific creativity and innovation: fluency, flexibility, originality, depth and elaboration, problem-solving, and diversity of approaches. Overall, fluency recorded the highest mean score (M = 3.09, SD = 0.313), interpreted as "very satisfactory," indicating strong ability to generate multiple ideas. The remaining indicators—flexibility (M = 2.44, SD = 0.245), originality (M = 2.52, SD = 0.162), depth and elaboration (M = 2.81, SD = 0.195), problem-solving (M = 2.76, SD = 0.215), and diversity of approaches (M = 2.80, SD = 0.233)—were all rated "satisfactory." The relatively low standard deviations suggest consistent performance across learners, indicating that tiered scaffolding contributed to more uniform learning outcomes.

These results imply that the Tiered Assistance Approach effectively supported students in generating and developing scientific ideas through structured AI-assisted scaffolding. Fluency was particularly enhanced as students were able to produce multiple responses during brainstorming activities, especially in disaster preparedness tasks such as earthquake evacuation planning. Across Tier 1, learners generated basic ideas with minimal support, which helped build fluency. In Tier 2, students improved their depth and elaboration by explaining and justifying responses with moderate guidance, though many explanations remained closely aligned with AI-generated suggestions. In Tier 3, learners applied concepts more independently in realistic scenarios, demonstrating satisfactory problem-solving and diversity of approaches in community-based evacuation planning tasks. However, flexibility and originality remained comparatively low, suggesting that while students could generate and explain ideas, they struggled to produce novel or divergent solutions. Transcript analysis confirmed that many learners relied heavily on ChatGPT outputs, often paraphrasing AI-generated responses rather than independently developing alternative ideas. This dependence likely contributed to limited originality despite active engagement and task completion. A classroom observation during an earthquake preparedness lesson further illustrated these findings. In Tier 1, students listed basic evacuation ideas such as emergency kits and safe routes, which contributed to high fluency. In Tier 2, they justified these ideas but frequently repeated AI-generated explanations. In Tier 3, students created evacuation plans for communities near fault lines, showing applied problem-solving but with similar solutions across groups due to reliance on AI suggestions.

These findings align with Tomlinson (2018), who emphasized that tiered instruction supports differentiated learning and consistent performance outcomes. They also support Vygotsky's Zone of Proximal Development and Hattie's work on scaffolding, highlighting that guided assistance enhances learner independence and achievement. Additionally, Zawacki-Richter et al. (2019) and Kasneci et al. (2023) note that AI tools can improve engagement, idea generation, and fluency through instant feedback and scaffolding. However, consistent with Dwivedi et al. (2023), excessive reliance on generative AI may limit originality and flexibility due to repetitive and conventional output patterns.

Table 2
Scientific Creativity and Innovation Post Assessment Scores in Socratic Prompting Approach and Tiered Assistance Approach

Scientific Creativity and Innovation Skills	GROUP	Mean	SD	Remarks
Fluency	Tiered	3.53	0.438	Outstanding
	Socratic	3.55	0.324	Outstanding
Flexibility	Tiered	3.15	0.652	Very Satisfactory
	Socratic	3.20	0.509	Very Satisfactory
Originality	Tiered	3.26	0.522	Very Satisfactory
	Socratic	3.20	1.592	Very Satisfactory
Depth and Elaboration	Tiered	2.90	0.615	Very Satisfactory

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	Socratic	3.24	0.524	Satisfactory
Problem-Solving	Tiered	3.33	0.566	Very Satisfactory
	Socratic	3.38	0.518	Very Satisfactory
Diversity of Approaches	Tiered	2.69	0.617	Very Satisfactory
	Socratic	3.28	0.403	Satisfactory
Total Scores	Tiered	50.53	6.423	Very Satisfactory
	Socratic	52.91	7.020	Very Satisfactory

Legend:4.0-3.5 Outstanding; 3.49-3.0 Very Satisfactory; 2.99-2.01 Satisfactory; 1.99 -1.00 Fairly Satisfactory; .99-0 Did not meet expectations

Table 2 compares Grade 7 learners' post-assessment scientific creativity and innovation under Socratic Prompting and Tiered Assistance approaches using ChatGPT. Both groups achieved "Very Satisfactory" to "Outstanding" performance across all dimensions, showing that AI-assisted instruction effectively supported scientific creativity development. Quantitatively, the Socratic Prompting group performed slightly higher in flexibility, depth and elaboration, problem solving, diversity of approaches, and overall score, while the Tiered Assistance group showed a marginal advantage in originality and comparable fluency. Specifically, Socratic Prompting recorded higher means in fluency (M = 3.55 vs. 3.53), flexibility (M = 3.20 vs. 3.15), depth and elaboration (M = 3.24 vs. 2.90), problem solving (M = 3.38 vs. 3.33), and diversity of approaches (M = 3.28 vs. 2.69). In contrast, Tiered Assistance slightly outperformed in originality (M = 3.26 vs. 3.20). Overall, Socratic Prompting also achieved a higher total mean score (M = 52.91 vs. 50.53).

Findings suggest that Socratic Prompting better supports reflective thinking, conceptual explanation, and diverse representations of ideas through guided questioning across exploration, connection, and application phases. Learners demonstrated stronger reasoning in explaining earthquake phenomena, proposing mitigation strategies, and presenting outputs such as infographics, evacuation plans, and prototypes. In contrast, Tiered Assistance promoted structured idea generation and systematic task completion through Hint–Prompt–Model scaffolding, enabling learners to produce organized outputs but often with similar structures due to reliance on AI-generated examples.

Qualitative evidence from student outputs and post-test tasks indicates that Socratic learners generated more varied and critically reasoned responses (e.g., structural reinforcement, early warning systems), while Tiered Assistance learners produced more uniform but well-organized solutions (e.g., emergency kits, evacuation zones). This pattern explains the higher performance of Socratic Prompting in depth, elaboration, and diversity of approaches, and the relatively stronger structured fluency seen in Tiered Assistance.

The findings align with Santos-Guevara et al. (2026) and Fakour and Imani (2025), which emphasize that AI-supported Socratic questioning enhances critical and reflective thinking. They are also consistent with Piaget's Constructivism and Vygotsky's scaffolding/ZPD, as well as Holmes et al. (2022), Kasneci et al. (2023), and Mai et al. (2024), highlighting that AI improves learning most effectively when integrated into structured inquiry and differentiated scaffolding, though instructional design determines whether outputs become deeply analytical or procedurally uniform.

Table 3
Test of Difference in the Scientific Creativity and Innovation Performance Formative Assessment scores across the Stages of Socratic Prompting Approach

One-Way ANOVA (Fisher's)

Scientific Creativity and Innovation Skills	F	df1	df2	P	Remarks
Fluency	64.5	2	135	<.001	Significant
Flexibility	151.1	2	135	<.001	Significant
Originality	46.4	2	135	<.001	Significant
Depth and Elaboration	69.0	2	135	<.001	Significant
Problem-Solving	97.9	2	135	<.001	Significant
Diversity of Approaches	82.3	2	135	<.001	Significant

Note: Tukey HSD post hoc tests showed significant pairwise differences across most comparisons. (See APPENDIX H)

Table 3 presents a One-Way ANOVA examining differences in Grade 7 students' Scientific Creativity and Innovation across the Socratic Prompting stages: Exploration, Connection, and Application. Results show statistically significant differences in all six dimensions—fluency ($F=64.5$, $p<.001$), flexibility ($F=151.1$, $p<.001$), originality ($F=46.4$, $p<.001$), depth/elaboration ($F=69.0$, $p<.001$), problem-solving ($F=97.9$, $p<.001$), and diversity of approaches ($F=82.3$, $p<.001$)—indicating that performance varied meaningfully across stages and rejecting the null hypothesis of no difference.

Overall, the findings suggest a progressive developmental pattern across the Socratic stages, where creativity and innovation improved from Exploration to Application. The highest variation was observed in flexibility ($F=151.1$), implying strong gains in perspective shifting and idea variation across stages. Substantial effects in problem-solving and diversity of approaches further indicate that students developed more solutions and applied knowledge more effectively at the Application stage. Although originality showed comparatively lower but still significant differences, students still demonstrated increasing innovation through guided questioning.

Tukey post hoc results confirmed significant pairwise differences across most stage comparisons ($p<.001$), particularly showing that Application and Connection stages outperformed Exploration across all dimensions (negative mean differences for Exploration vs. others reflect lower initial scores). Growth trends were generally incremental, with the strongest improvement occurring from Exploration to Application. Only a few comparisons (e.g., originality between Exploration and Application; diversity of approaches between Connection and Application) were not statistically significant, suggesting some plateauing in specific creative aspects.

These results indicate that Socratic Prompting with AI (ChatGPT) promotes staged cognitive development—from idea generation (Exploration), to conceptual linking (Connection), to applied reasoning and solution design (Application). This aligns with Fakour and Imani (2025), Santos-Guevara et al. (2026), Favero et al. (2024), and Singh et al. (2025), which emphasize that guided questioning and metacognitive prompting enhance reasoning, flexibility, and conceptual understanding. However, in line with Lee et al. (2025), the findings also suggest that AI's benefits depend on pedagogical design, as structured Socratic prompting was necessary to prevent passive answer-taking and instead foster active, progressive cognitive growth.

Table 4

Test of Difference in the Scientific Creativity and Innovation Performance Formative Assessment Scores

of the respondents in the Guardrails approaches when categorized according to levels of Tiered assistance approaches

One-Way ANOVA (Welch's)

Scientific Creativity and Innovation Skills	F	df1	df2	p	Remarks
Fluency	**13.28**	**2**	**24.0**	**<.001**	**Significant**
Flexibility	**2.54**	**2**	**23.8**	**0.100**	**Not Significant**
Originality	**7.15**	**2**	**25.0**	**0.004**	**Significant**
Depth and Elaboration	**1.86**	**2**	**23.3**	**0.178**	**Not Significant**
Problem-Solving	**4.44**	**2**	**22.2**	**0.024**	**Significant**
Diversity of Approaches	**5.56**	**2**	**21.7**	**0.011**	**Significant**

Note. Games–Howell post hoc tests showed the following pairwise comparisons across groups. (See Appendix H)

Table 4 shows that the Tiered Assistance Approach produced mixed but statistically significant effects on learners' scientific creativity and innovation. Significant differences were found in fluency ($F = 13.28$, $p < .001$), originality ($F = 7.15$, $p = .004$), problem solving ($F = 4.44$, $p = .024$), and diversity of approaches ($F = 5.56$, $p = .011$), indicating that varying levels of scaffolded support influenced learners' ability to generate ideas, produce outputs, solve problems, and present information in different forms. However, no significant differences were observed in flexibility ($F = 2.54$, $p = .100$) and depth and elaboration ($F = 1.86$, $p = .178$), suggesting limited impact of tiered assistance on perspective shifting and explanatory depth.

Post hoc results showed that learners in Tier 3 (Model) generally outperformed those in lower tiers in fluency, problem solving, and diversity of approaches, highlighting the role of worked examples and demonstrations in improving structured idea generation and task performance. However, originality followed a non-linear pattern across tiers, suggesting that moderate scaffolding sometimes led to reliance on provided examples rather than independent idea generation. Overall, Tiered Assistance was most effective in supporting structured outputs and applied problem solving, but less effective in enhancing higher-order thinking skills such as flexibility and elaboration.

These findings align with Tomlinson (2018), who emphasized that tiered instruction improves learning by matching support to learner needs, and with Suprayogi et al. (2017) and Smale-Jacobse et al. (2019), who found that differentiated instruction enhances engagement and task performance. Similarly, Pozas et al. (2020) noted that scaffolding supports multiple problem-solving strategies, which corresponds to the observed gains in fluency and diversity of approaches. However, the lack of significant improvement in flexibility and depth and elaboration is consistent with Deunk et al. (2018), who argued that differentiated instruction may not automatically enhance higher-order thinking unless explicitly targeted. These results are also consistent with Vygotsky's scaffolding theory, which explains that while guided support enables task completion within the Zone of Proximal Development, excessive reliance on structured assistance may limit independent reasoning and reflective thinking.

Table 5
Significant differences between the Scientific Creativity and Innovation Performance Post Assessment Scores of the two groups of respondents exposed to the Guardrails approaches

Independent Samples T-Test

Tiered – Socratic		Statistic	df	P	Mean difference	SE difference
Fluency	Student's t	-0.293[a]	87.0	0.770	-0.0238	0.0814
	Welch's t	-0.290	77.3	0.773	-0.0238	0.0822
Flexibility	Student's t	-0.444[a]	87.0	0.658	-0.0549	0.1236
	Welch's t	-0.440	79.5	0.661	-0.0549	0.1246
Originality	Student's t	0.240	87.0	0.811	0.0611	0.2548
	Welch's t	0.246	55.2	0.806	0.0611	0.2479
Depth and Elaboration	Student's t	-2.808	87.0	0.006	-0.3398	0.1210
	Welch's t	-2.793	82.8	0.006	-0.3398	0.1217
Problem-Solving	Student's t	-0.477	87.0	0.634	-0.0549	0.1149
	Welch's t	-0.476	85.0	0.635	-0.0549	0.1153
Diversity of Approaches	Student's t	-5.430[a]	87.0	<.001	-0.5966	0.1099
	Welch's t	-5.356	71.6	<.001	-0.5966	0.1114

Note. H_a $\mu_1 \neq \mu_2$

[a] Levene's test is significant ($p < .05$), suggesting a violation of the assumption of equal variances

Table 5 shows the results of an independent samples t-test comparing Grade 7 learners exposed to the Socratic Prompting Approach and the Tiered Assistance Approach in terms of scientific creativity and innovation. No significant differences were found in fluency ($t = -0.293$, $p = 0.770$), flexibility ($t = -0.444$, $p = 0.658$), originality ($t = 0.240$, $p = 0.811$), and problem solving ($t = -0.477$, $p = 0.634$), indicating that both AI-assisted approaches similarly supported learners in generating ideas, shifting perspectives, producing creative outputs, and solving scientific problems. However, significant differences were observed in depth and elaboration ($t = -2.808$, $p = 0.006$) and diversity of approaches ($t = -5.430$, $p < .001$), with the Socratic Prompting group outperforming the Tiered Assistance group. This suggests that Socratic questioning more strongly promoted detailed scientific explanations and the use of varied representations in expressing ideas. Levene's test results for some variables indicated unequal variances, supporting the use of Welch's t-test for more robust comparison. Overall, both approaches were equally effective in supporting foundational aspects of scientific creativity, but the Socratic Prompting Approach was more effective in enhancing higher-order thinking skills, particularly elaboration and diversity of approaches.

These findings are consistent with Chi and Wylie's (2018) ICAP framework, which emphasizes that interactive and constructive learning promotes deeper understanding, and with Holmes et al. (2019), who highlight the role of AI-driven questioning in developing critical reflection. They also align with Kasneci et al. (2023), who argue that generative AI is most effective in dialogical, inquiry-based learning, and with Mollick and Mollick (2023), who emphasize the importance of open-ended prompts in producing richer learner responses. Finally, the results support Tomlinson (2018), Deunk et al. (2018), and Zhai et al. (2021), which suggest that while scaffolding and AI support enhance task completion and engagement, deeper learning outcomes depend on reflective and inquiry-oriented instructional design.

6. Conclusion

Based on the findings of the study, the following conclusions were drawn:

1. There are significant differences in the Scientific Creativity and Innovation skills of learners across the stages of the Socratic Prompting Approach. Hence, the null hypothesis is not supported. This indicates that learners' performance improved progressively across the exploration, connection, and application stages.

2. There are significant differences in selected dimensions of scientific creativity and innovation across levels of the Tiered Assistance Approach, specifically in fluency, originality, problem solving, and diversity of approaches. However, no significant differences were found in flexibility and depth and elaboration. Therefore, the null hypothesis is not supported for most dimensions but is partially retained for flexibility and depth-related skills.

3. There is no significant difference in the overall post-assessment scores between the Socratic Prompting and Tiered Assistance groups, although mean scores slightly favor the Socratic Prompting Approach. Thus, the null hypothesis is supported, indicating that both instructional approaches are comparably effective in enhancing overall scientific creativity and innovation.

7. Recommendations

Based on the results and conclusions of the study, the following recommendations are offered:

1. Since both Socratic Prompting and Tiered Assistance were found to be similarly effective in improving students' scientific creativity and innovation, schools are encouraged to adopt AI-assisted instructional approaches within a structured guardrails framework. This should be supported by teacher training programs and institutional policies that promote the ethical, guided, and responsible use of AI tools such as ChatGPT.

2. Given that Socratic Prompting strengthens higher-order thinking skills (e.g., depth and elaboration, problem solving, and diversity of approaches), while Tiered Assistance supports structured idea generation and fluency, educators are encouraged to integrate both approaches in lesson design. Instructional activities may be sequenced from highly structured tasks toward more open-ended inquiry tasks to gradually develop learners' cognitive and creative capacities.

3. Teachers are further encouraged to combine Socratic questioning with tiered scaffolding strategies in classroom practice. Socratic Prompting should be used to promote reflective thinking through open-ended and probing questions, while Tiered Assistance may be used to

support learners who require structured guidance in idea generation and task completion, particularly during initial stages of learning.

4. Future researchers are encouraged to examine the long-term effects of combining Socratic Prompting and Tiered Assistance within AI-assisted learning environments. Further studies may also include additional variables such as learner motivation, metacognitive skills, collaboration, and engagement. Similar studies may be conducted across other grade levels and subject areas to validate and extend the findings of this research.

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