Active Vs Passive Incubation: Which Method Leads to Eureka Moment in Non-Routine Problem Solving?

Mary Joy D. Garde[1], Faith D. Menodiado[2], Mary Chris Y. Pritos[3], Genesis G. Camarista[4]

West Visayas State University-Himamaylan City Campus, Brgy. Caradio-an, Himamaylan City, 6108, Philippines

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ABSTRACT

This study looked at how students' Eureka experiences and performance in solving non-routine mathematical problems were affected by both active and passive incubation. It investigated whether doing a cognitively stimulating task (active incubation) or resting without mental engagement (passive incubation) affects problem-solving outcomes. It was based on Wallas's (1926) four-stage model of creativity and the unconscious work hypothesis. 43 purposefully chosen special science high school students participated in the study, which used a quantitative descriptive–comparative design. They worked through non-routine math tasks over the course of two sessions, separated by an incubation period. The instruments were determined to be dependable after being properly validated and pilot tested. The Kruskal–Wallis H test, Spearman's rho correlation, and descriptive statistics were used to examine the data. The findings showed that students who were actively incubated outperformed those who were passively incubated, though differences were not statistically significant. The *Eureka* experience also showed no significant correlation with performance. The findings highlight the complex role of incubation and insight in problem solving and suggest incorporating structured incubation and metacognitive strategies in mathematics instruction.

Keywords: Eureka moment; non-routine problem-solving; passive incubation; active incubation; mathematical creativity

INTRODUCTION

Henri Poincaré's experience with Fuchsian functions illustrates how moments of insight—or Eureka moments—often occur after a period of rest from conscious problem-solving, a process known as incubation. Building on this phenomenon, the present study focuses on the role of incubation in mathematical problemsolving among special science high school students. As emphasized in *The Art of Problem Solving* (Camarista, 2016), effective problem-solving goes beyond computation and involves deep thinking, reflection, and moments of insight that emerge when the mind is allowed to pause and reorganize ideas. Grounded in Wallas' (1926) Four-Stage Model of Creativity and Gilhooly's (2013) elaboration on the incubation effect, this study explores how different incubation types—**active** (filled, cognitively demanding tasks) and **passive** (unfilled, cognitively undemanding tasks)—affect students' capacity to experience Eureka moments and improve performance in solving non-routine mathematical problems.

Specifically, the study seeks to: (a) determine the overall non-routine problem-solving performance of students and compare it between those who engage in active and passive incubation; (b) identify whether there is a significant difference in problem-solving performance among students who underwent different incubation conditions—active with Eureka, active without Eureka, passive with Eureka, and passive without Eureka; and (c) examine whether a significant relationship exists between experiencing a Eureka moment and non-routine

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problem-solving performance, regardless of incubation type. These specific objectives (SOPs) guide the investigation into how incubation type and insight interact to influence creative mathematical thinking and performance.

Ultimately, this study aims to determine whether active or passive incubation more effectively promotes Eureka experiences and enhances students' problem-solving skills. By clarifying these effects, the research intends to provide evidence-based insights that can inform classroom practices and curriculum design in mathematics education. The results will contribute to developing strategies that foster cognitive flexibility, creativity, and persistence—essential qualities in problem-solving not only in mathematics but in broader learning contexts as well.

THEORETICAL FRAMEWORK

Sio (2007) cited numerous studies (e.g., Murray & Denny, 1969; Patrick, 1986; Penney, Godsell, Scott, & Balsom, 2004; Silveira, 1971) in which participants who underwent a filled incubation period outperformed those who worked continuously on the problem. Likewise, Sio also referenced researches (e.g., Patrick, 1986; Penney et al., 2004; Smith & Blankenship, 1989) that found participants who experienced a filled incubation period performed better than those who either rested or continued working uninterrupted. Specifically, Patrick (1986), as cited by Sio and Ormerod (2009), noted that participants who underwent a filled incubation period outperformed those who experienced an unfilled one. These findings support one of the theoretical foundations of this study: the unconscious work hypothesis. This hypothesis proposes that incubation effects result from the continued, unconscious processing of problem-related material (Gilhooly et al., 2012). Gilhooly (2016) further emphasized that unconscious problem-solving processes are activated when attention is directed toward unrelated mental tasks, suggesting that a certain level of cognitive engagement during incubation may enhance subsequent performance.

In contrast, this study also considers the conscious work hypothesis, which contradicts the unconscious work hypothesis. It posits that unfilled incubation periods, such as rest or mental disengagement, produce stronger incubation effects than filled ones (Sio & Ormerod, 2009). According to Browne and Cruse (1988), as cited in the meta-analysis of Sio and Ormerod (2009), participants who rested during incubation performed better than those who engaged in other tasks. However, the same meta-analysis also cited studies (e.g., Olton & Johnson, 1976; Smith & Blankenship, 1989) that found no significant difference in performance between filled and unfilled incubation periods.

Given these inconsistent findings, this study seeks to contribute to the growing body of knowledge by determining which type of incubation (active or passive) more effectively promotes cognitive breakthroughs and success in problem-solving. Additionally, this study aims to identify which incubation method students are more likely to prefer and engage within the context of problem-solving.

METHODOLOGY

Research Design

This study adopted a quantitative research design, which focused on collecting and analyzing numerical data to describe and examine relationships between variables. Quantitative research involves systematic investigation using statistical methods to test hypotheses or answer research questions based on measurable data (Subedi, 2023). Specifically, this study sought to compare the effects of active and passive incubation on students' non-routine problem-solving performance and the occurrence of Eureka moments.

Participants

The participants of the study included 43 Grade 7 Special Science students from a high school in Negros Occidental, Philippines. A purposive sampling technique, a type of non-probability sampling wherein participants are selected based on specific characteristics or criteria (Bullard & Eric, 2024), was employed to determine the participants of the study. All selected Grade 7 Special Science students were included based on their membership in the Special Science class, which was specifically chosen due to the students' anticipated higher engagement in complex problem-solving tasks. Grade 7 students were chosen because they were at a developmental stage where they had limited exposure to problem-solving activities compared to higher grade levels, making them ideal participants for examining the effects of incubation on problem solving.

Instruments

The instruments used for data collection include: (a) eight non-routine mathematics problems adapted from The Art of Problem Solving by Camarista (2016); (b) a questionnaire designed to identify the incubation method used during the break and the occurrence of Eureka moments; and (c) a researcher-made Non-Routine Problem Solving Rubric. The questionnaire was validated by a licensed guidance counselor and a Mathematics teacher to ensure it accurately captures incubation behaviors and insight experiences. The rubric, which measures the accuracy, completeness, organization and correctness of solutions in students' non-routine problem-solving task, was reviewed and validated by three mathematics teachers to ensure content validity. Instruments underwent pilot testing to ensure reliability and clarity of administration procedures.

Before conducting the actual research study, the researcher first conducted a pilot test to ensure the administrability of the non-routine problems and the clarity of the research procedures. A request letter seeking approval was sent to the principal and the Grade 7 Special Science teacher of the selected school. Upon receiving the necessary approvals, the researcher proceeded with the administration of the problem-solving tasks to students.

Data Collection

The data collection was conducted in a single quantitative phase. The participants were tasked to solve eight non-routine mathematical problems divided into two separate 20-minute sessions, with a 15-minute incubation break in between. During the break, students engaged in either active incubation (e.g., performing a different mental task, puzzle, or other cognitively engaging activity) or passive incubation (e.g., resting, daydreaming, or sitting quietly).

At the start of the break, students' test papers were collected for documentation purposes and returned afterward. To support data analysis, photographs of their initial problem-solving processes were taken. After the second session, the questionnaire was administered to determine which incubation method each student used and whether they experienced a Eureka moment.

The students' responses to the non-routine problems were evaluated by three Bachelor of Secondary Education Major in Mathematics fourth-year students using the researcher-designed Non-Routine ProblemSolving Performance Rubric, ensuring consistency and objectivity in scoring.

Data Analysis

The data collected were analyzed using descriptive and inferential statistics. To determine the overall non-routine problem-solving performance of students and when grouped according to incubation type, descriptive statistics such as the mean, standard deviation, and frequency were used (Hayes, 2024).

To determine the difference between the four incubation conditions (active incubation with Eureka moment, active incubation without Eureka moment, passive incubation with Eureka moment, and passive incubation without Eureka moment), the Kruskal–Wallis H test was used. The Kruskal–Wallis test is a nonparametric statistical test used to compare two or more independent groups on a continuous or ordinal (discrete) variable. It determines whether there are statistically significant differences between the median ranks of the groups (McClenaghan, 2024).

To determine the relationship between experiencing a Eureka moment and non-routine problem-solving performance, regardless of incubation type, Spearman's rho correlation test was used. Spearman's rank

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correlation is a statistical technique used to understand the relationship between two variables when the relationship is not linear (McClenaghan, 2024).

Ethical Considerations

Participation in the study was voluntary. Informed consent was obtained from all participants, ensuring that they fully understood the nature, purpose, and procedures of the study. The confidentiality of participants was strictly maintained. Names were collected only for the purpose of scoring and data organization, and pseudonyms or codes were used in presenting results to ensure anonymity.

RESULTS AND DISCUSSION

Non-routine Problem-Solving Performance of Students as a Whole and when grouped as to which Incubation Method They Engaged into the present study sought to examine the effects of active and passive incubation on students' nonroutine problem-solving performance, as well as the role of experiencing a "Eureka" moment during the incubation process. The results revealed that, overall, the participants (n = 43) demonstrated an average level of performance (M = 41.53, SD = 12.95). When grouped by incubation type, students in the active incubation condition achieved a higher mean score (M = 44.21, SD = 13.23) than those in the passive incubation condition (M = 39.40, SD = 12.60).

Further analysis showed that among the active incubation subgroups, students who did not experience a Eureka moment (*M* = 47.46, *SD* = 14.17) slightly outperformed those who did (*M* = 41.85, *SD* = 12.65). Similarly, within the passive group, those with Eureka moments (*M* = 40.36, *SD* = 14.13) scored marginally higher than those without (*M* = 38.07, *SD* = 10.67), although all were within the average to low performance range. Collectively, these results suggest that active incubation may provide a modest advantage in facilitating problem-solving compared to passive incubation, though the presence of a subjective Eureka experience does not necessarily correspond to better performance outcomes.

Table 1 Non-routine Problem-Solving Performance of Students as a Whole and when Grouped as to which Incubation Method (Active with Eureka, Active without Eureka, Passive with Eureka and Passive without Eureka) They Engaged Into

Type of Incubation	*n*	Mean	*SD*	Verbal Description
Active	19	44.21	13.23	Average
Active with Eureka	11	41.85	12.65	Average
Active without Eureka	8	47.46	14.17	Average
Passive	24	39.40	12.60	Average
Passive with Eureka	14	40.36	14.13	Average
Passive without Eureka	10	38.07	10.67	Low
Overall	43	41.53	12.95	Average

Note: 76.81-96.00 Very High; 57.61-76.81 High; 38.41-57.60 Average; 19.21-38.40 Low; 0.00-19.20 Very Low

The findings can be interpreted within a cognitive incubation framework, which posits that breaks from direct problem-solving—whether active or passive—promote the reorganization of mental representations, leading to improved performance or moments of insight. In this study, incubation type (active vs. passive) served as the independent variable influencing non-routine problem-solving performance (dependent variable), while the Eureka experience functioned as a subjective indicator of insight.

Recent cognitive theories (Gilhooly, et. al., 2016) emphasize that incubation operates through interacting unconscious and conscious processes that allow individuals to escape fixation and form novel associations. Theoretically, incubation facilitates problem solving through three interrelated mechanisms:

Fixation reduction, wherein stepping away from a problem allows unproductive assumptions to decay (Peñaloza & Calvillo, 2012); Unconscious associative processing, in which unattended cognitive mechanisms continue reorganizing information relevant to the problem (Zedelius & Schooler, 2016); and Mind-wandering or cognitive flexibility, where low-demand activities promote associative spreading that contributes to insight (Mills et al., 2018).

Within this framework, active incubation (performing a cognitively demanding, unrelated task) may maintain moderate cognitive engagement that enables associative restructuring, where an individual reorganizes his or her mental representation of a problem after failed attempts (Sio & Ormerod, 2009), whereas passive incubation (complete rest or inactivity) may produce fewer new associations. Thus, the slightly higher mean scores observed for the active groups are consistent with current theoretical models suggesting that cognitively demanding activity facilitates an active and gradual yet unconscious cognitive processing during incubation (Sio & Ormerod, 2016; Sio & Ormerod, 2009). In fact, meta-analytic evidence indicates that engaging in a filled incubation during the interval can be more beneficial for problem solving than complete rest, as it may prevent mental fixation while still allowing unconscious associative processes to operate. Lowdemand tasks or passive incubation can occupy a student's attention, preventing them from focusing on problem associations and restructuring (Sio & Ormerod, 2009). This suggests that moderate cognitive engagement best supports the reorganization of problem representations that lead to insight and improved performance.

The observed descriptive advantage of active incubation supports recent evidence that the type of interpolated activity moderate incubation effects. Meta-analytic work and experimental replications (Sio et al., 2021) confirm that cognitively demanding activities produce stronger incubation benefits than either rest or highly demanding activities. Likewise, Mills et al. (2018) demonstrated that engaging in undemanding activities that foster spontaneous thought and mind-wandering promotes greater creative problem-solving success compared to passive rest, corroborating the cognitive value of active incubation conditions.

Interestingly, the finding that the active without Eureka group achieved the highest mean suggests that enhanced performance can occur even without conscious awareness of insight. This aligns with more recent evidence that performance improvement during incubation may occur through unconscious restructuring, rather than a sudden conscious "Aha!" moment (Kounios & Beeman, 2015). Similarly, Gilhooly (2016) emphasized that not all problem-solving success is accompanied by a vivid insight experience; many solutions emerge gradually through implicit cognitive processes or analytical reasoning.

The relatively lower means for passive groups may reflect the limited cognitive stimulation inherent in passive incubation, which restricts associative reactivation of memory networks. Contemporary models suggest that completely passive rest may not optimally balance memory consolidation and associative activation, especially for complex, non-routine problems that require creative recombination rather than retrieval as under the conscious work hypothesis, highly activated contents of working memory is necessary (Gilhooly, 2016).

Overall, the results indicate that while incubation contributes modestly to problem-solving, its effects are subtle and context-dependent. The slight advantage of active incubation supports the view that mild cognitive engagement during rest can reactivate semantic networks, facilitating restructuring even without conscious insight. This interpretation aligns with a dual-process perspective on creative problem-solving— distinguishing between the subjective experience of insight and objective cognitive restructuring (Zedelius & Schooler, 2016).

Difference in Non-Routine Problem-Solving Performance Among Students Who Underwent Different Incubation Types

The results of the Kruskal–Wallis H test (H = 2.329, p = .507) indicate that there is no statistically significant difference in non-routine problem-solving performance among the four incubation conditions: active with eureka, active without eureka, passive with eureka, and passive without eureka. The mean ranks suggest that students in the active without eureka group (Mean Rank = 27.38) performed slightly better on non-routine problem-solving tasks compared to those in the active with eureka (Mean Rank = 22.68), passive with eureka (Mean Rank = 20.75), and passive without eureka (Mean Rank = 18.70) groups. However, these differences were not statistically significant at the 0.05 level.

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This finding implies that the type of incubation—whether active or passive, and whether accompanied by a eureka moment or not—did not substantially affect students' problem-solving performance. The results support the idea that while incubation may contribute to creative insight or solution finding, its measurable effects on performance in non-routine mathematical tasks are subtle and context-dependent (Kohn & Smith, 2020).

Table 2 Difference in the Non-Routine Problem-Solving Performance Among the Four Incubation Conditions

Eureka	*n*	Mean Rank	Kruskal-Wallis H	Sig
Active with Eureka	11	22.68	2.329	.507
Active without Eureka	8	27.38		
Passive with Eureka	14	20.75		
Passive without Eureka	10	18.70		

Note: The Kruskal–Wallis H test indicated no statistically significant difference in non-routine problem-solving performance among the four incubation conditions, $H(3) = 2.33$, $p = .507$. Significance level set at $p < .05$.

The study was grounded in the Dual-Process Theory of Creativity (Allen & Thomas, 2011) and the Incubation Theory of Problem-Solving (Wallas, 1926), both of which propose that problem-solving involves alternating periods of conscious effort and unconscious cognitive processing. Within this framework, active incubation involves engaging in cognitively demanding tasks that can facilitate subconscious restructuring of the problem, whereas passive incubation involves rest or disengagement from cognitive effort (Gilhooly, 2016).

However, the current findings align with recent evidence suggesting that the benefits of incubation are not uniform across task types and depend on individual differences such as cognitive style, working memory, and domain familiarity (Zedelius & Schooler, 2016). The lack of significant differences among incubation conditions may indicate that students have not yet developed sufficient metacognitive awareness to harness incubation effectively, or that the task duration was not long enough to activate meaningful incubation effects (Krawczyk et al., 2022). Another reason is also the existence of multiple types of problem-specific incubation effect. Problems that require gaining insight to find a unique solution do not always improve through incubation in every situation (Sio & Ormerod, 2009).

Recent research continues to report mixed findings on incubation and creative problem-solving. For instance, Ritter et al. (2021) demonstrated that engaging in cognitively high-demand, unrelated activities during incubation enhances creative output, supporting the notion of active incubation. Conversely, Abdulla and Cramond (2017) found that passive incubation, such as taking mental rest, can also yield benefits when the problem requires sudden insight rather than systematic analysis.

In the context of mathematics education, non-routine problem-solving requires advanced cognitive operations such as divergent thinking, abstraction, and persistence (Leikin, 2019; Schoenfeld, 2016). The nonsignificant results in this study may suggest that success in such tasks depends more on domain-specific knowledge and cognitive flexibility than on the specific mode of incubation (Nijstad & De Dreu, 2020).

Interestingly, the finding that the *active without eureka* group slightly outperformed others aligns with studies showing that problem-solving success often emerges from gradual analytical reasoning rather than sudden insight (Beaty et al., 2019). This reinforces the pedagogical value of encouraging students to integrate both deliberate reasoning and creative reflection in solving complex problems.

Relationship Between Experiencing a 'Eureka' Moment and Non-Routine Problem-Solving Performance, Regardless of Incubation Type

The results of the Spearman's rho correlation test ($\rho = .038$, $p = .809$) indicate that there is no statistically significant relationship between experiencing a "Eureka" moment and non-routine problemsolving performance, regardless of whether students underwent active or passive incubation. This means that the occurrence of a subjective “Eureka” experience—or sudden insight—was not reliably associated with higher problem-solving scores among participants.

In other words, while some students may have reported experiencing moments of sudden realization during problem-solving, these insights did not necessarily translate into measurable performance gains in solving non-routine mathematical problems.

Table 3 Relationship Between Experiencing a 'Eureka' Moment and Non-Routine Problem-Solving Performance, Regardless of Incubation Type

	“Eureka” Moment		Problem-Solving Performance	
	Spearman’s Rho	p-value	Spearman’s Rho	p-value
“Eureka” Moment	-	-	.038	.809
Problem-Solving Performance	.038	.809	-	-

Note: Spearman’s rho correlation was computed (N = 43). The relationship between experiencing a "Eureka" moment and problem-solving performance was not statistically significant ($\rho = .038$, $p = .809$). Significance set at $p < .05$.

The result aligns with the Dual-Process Theory of Creativity (Allen & Thomas, 2011) and Wallas’s (1926) four-stage model of creative problem-solving—preparation, incubation, illumination (“Eureka”), and verification. The "Eureka" or illumination stage represents a subjective experience of sudden understanding, but according to cognitive theories, not all insights result in accurate or efficient solutions (Kounios & Beeman, 2014). The absence of a significant relationship in this study suggests that experiencing insight alone is insufficient to guarantee problem-solving success; rather, it must be accompanied by effective verification and analytical evaluation.

Within this theoretical framework, the findings can be interpreted to mean that Eureka experiences may reflect an affective or metacognitive awareness of progress, but they do not necessarily indicate successful cognitive restructuring of the problem. This distinction supports the argument that creative insight and problem-solving performance are related but distinct constructs—one cognitive-emotional, the other evaluative and outcome-based (Danek & Wiley, 2017).

Prior research in cognitive psychology and educational problem-solving has shown inconsistent relationships between reported “Eureka” experiences and actual task performance. For instance, Metcalfe (1986) observed that the “feeling of knowing” or sudden insight often emerges even when the solution is incorrect, suggesting that such experiences may be subjectively compelling but not always valid indicators of cognitive success. Similarly, Kounios and Beeman (2014) demonstrated through neuroimaging studies that while insight involves distinct right-hemisphere activation patterns associated with sudden comprehension, it does not guarantee accuracy without subsequent analytical verification.

In the field of mathematics education, non-routine problem-solving requires iterative reasoning, reflection, and monitoring (Schoenfeld, 2016). Although insight moments can spark motivation and creativity, they rarely suffice to achieve accurate solutions without deliberate planning and verification (Carlson & Bloom, 2005). This view aligns with contemporary perspectives in problem-solving research, which emphasize that genuine understanding and success emerge from a balance between intuitive thinking and systematic, reflective reasoning (Kuzle, 2013).

The current study’s non-significant correlation between Eureka experiences and performance thus reinforces the integrative model of problem-solving, which posits that both insight (creative cognition) and analytic reasoning (critical cognition) are essential but operate independently (Gilhooly, 2016). Educators, therefore, should not equate the presence of a “Eureka” moment with mastery or competence but should design learning experiences that develop students’ ability to evaluate and refine insights systematically.

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CONCLUSION

The present pattern of results—where active incubation produced a modest descriptive advantage over passive incubation but no statistically significant group differences, and where subjective "Eureka" reports did not correspond with higher scores—is probably attributable to multiple, interacting factors. First, it is likely that the cognitive demands of the interpolated tasks moderated the efficacy of incubation. Contemporary metaanalytic and experimental work indicates that cognitively demanding activities tend to facilitate associative processing and creative restructuring more effectively than either rest or highly demanding tasks (Sio & Ormerod, 2007). Therefore, since the active condition in this study involved engaging in cognitively demanding tasks, it likely facilitated the unconscious reactivation of related mental associations, resulting in slightly higher mean performance, while passive rest may have led to weaker associative activation (Mills et al., 2018).

Second, the dissociation between subjective insight and objective performance suggests that Eureka experiences are not reliable proxies for the cognitive restructuring that produces correct solutions. Recent cognitive-neuroscience and behavioral studies show that the phenomenology of insight (the felt "Aha!") can be dissociated from solution accuracy; participants sometimes report compelling insights that are incorrect, and conversely they often reach correct solutions without a vivid subjective epiphany (Danek & Wiley, 2017; Kounios & Beeman, 2020). Therefore, in the present sample, participants who reported Eureka moments may have experienced affective or metacognitive signals of perceived understanding that did not translate into validated problem solutions.

Third, the null inferential results may perhaps reflect limited statistical power and score variability. With relatively small subgroup sizes and performance values concentrated in the "average" band, modest but meaningful effects could remain undetected (Krawczyk, Meyer, & Radvansky, 2022). In addition, the heterogeneity of students' prior knowledge and problem-solving strategies likely introduced noise that attenuated group differences—non-routine mathematical performance typically depends heavily on domain knowledge and metacognitive skill, which may overshadow short incubation manipulations (Leikin, 2019; Schoenfeld, 2016).

Fourth, the pattern in which active without Eureka produced the highest mean suggests that unconscious or incremental processes—rather than dramatic conscious insight—may underlie many successful problem resolutions. Contemporary theory emphasizes that incubation can enable slow, implicit restructuring and spreading activation that improve solution probability without producing a conscious "Aha!" (Gilhooly, 2016). Thus, performance gains may accrue through gradual integration of remote associations during the incubation interval rather than through a single transformative moment.

Fifth, individual differences in metacognition and reporting thresholds probably influenced who labeled an experience as a "Eureka" and who did not. Some students may be more likely to endorse a subjective insight label for minor internal shifts, whereas others reserve such labels for dramatic, unmistakable moments; this variability can obscure relations between reported insight and objective performance (Zedelius & Schooler, 2016). Accordingly, the weak correlation observed here ($\rho = .038$) may partly reflect measurement noise in the binary assessment of Eureka rather than a true absence of cognitive relationships.

Finally, it is possible that task characteristics—including problem complexity, preparation time, and similarity between the interpolated and target tasks—moderated incubation effects. Recent work indicates that incubation benefits are sensitive to the match between the cognitive processes engaged during the break and those required for the target problem. If the incubation activities here did not optimally scaffold the specific types of associative recombination required by the non-routine tasks, then potential benefits would be limited.

In general, the findings probably reflect a combination of (a) task-dependent incubation dynamics favoring active breaks, (b) dissociation between the subjective phenomenology of Eureka and objective correctness, (c) limited power and individual difference noise, (d) the role of unconscious or incremental process, (e) the predominance of domain knowledge and metacognitive skills in mathematical problem solving, and (f) the influence of task characteristics. Future research that increases sample size, manipulates incubation load and content systematically, and uses graded or multimodal measures of insight (behavioral, self-report, and neurocognitive) will likely clarify which pathways—conscious or unconscious—most robustly contribute to successful non-routine problem solving.

RECOMMENDATIONS

The findings of this study underscore the nuanced and context-dependent nature of incubation effects and insight experiences in non-routine mathematical problem-solving. Although active incubation showed a modest descriptive advantage over passive incubation, no statistically significant differences were observed among the groups. Similarly, experiencing a "Eureka" moment did not predict higher problem-solving performance. From these findings, several practical, pedagogical, and research-oriented recommendations are proposed.

Integrate Structured Active Incubation Activities in Mathematics Instruction. Given the slight advantage observed in the active incubation condition, educators may consider deliberately incorporating active tasks during problem-solving lessons. These could include activities such as pattern recognition puzzles, light drawing, or brief movement breaks—cognitively undemanding tasks that promote mind-wandering and associative thinking without full disengagement. Such activities may help students unconsciously reorganize problem representations, supporting insight and creative connections in mathematical reasoning.

Teach Students Metacognitive Strategies for Managing Fixation. The results suggest that incubation benefits may depend on learners' ability to regulate their focus and manage fixation. Teachers may therefore provide explicit instruction on metacognitive strategies, such as recognizing impasses, taking strategic breaks, and shifting perspectives when encountering difficult problems. These strategies help students use incubation periods productively—encouraging reflection and mental restructuring rather than disengagement.

Reframe the Role of "Eureka" Experiences in Problem-Solving. The absence of a significant relationship between "Eureka" experiences and problem-solving success highlights the need to educate learners about the fallibility of subjective insight. Educators may help students understand that intuitive "Aha!" moments, while motivational, are not always indicators of correctness. Teachers can model how to verify and evaluate solutions analytically following intuitive breakthroughs—reinforcing the dual-process nature of problem-solving, which integrates both creative and analytical cognition.

Design Learning Environments That Balance Creativity and Analytical Rigor. To optimize problem-solving instruction, teachers may create classroom conditions that balance periods of creative exploration with structured analytical evaluation. For example, after posing non-routine problems, educators can provide incubation breaks followed by reflective discussions on multiple solution pathways. This approach aligns with the Dual-Process Theory of Creativity, which posits that effective problem-solving arises from alternating between intuitive idea generation and deliberate verification.

Encourage Collaboration and Verbalization During Incubation Phases. Collaborative learning contexts can amplify incubation effects by exposing students to diverse thought processes. Allowing students to discuss partially formed ideas or intuitions during breaks may facilitate the reorganization of mental representations through social scaffolding and elaboration. Structured peer dialogue and think-aloud protocols can make otherwise unconscious restructuring processes more explicit, leading to deeper understanding.

Enhance Research on Incubation and Insight Through Methodological Refinement. Future studies may employ larger and more diverse samples to increase statistical power and generalizability. Moreover, using multi-dimensional measures of insight—including behavioral indicators, self-reports, and physiological or neurocognitive markers—would capture the complex nature of Eureka experiences more accurately. Varying the duration, content, and cognitive load of incubation activities can also help identify optimal conditions for promoting problem-solving success.

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Provide Professional Development on Creative Cognition for Mathematics Teachers. Teacher training programs may include modules on creative cognition and incubation-based learning. By deepening teachers' understanding of how unconscious associative processes support reasoning, they can better design activities that foster flexible thinking, resilience, and innovation in mathematics classrooms.

In essence, the present findings call for a pedagogical shift from treating "Eureka" moments as endpoints of discovery toward viewing them as transitional signals within a broader cognitive process. By integrating active incubation techniques, promoting metacognitive awareness, and balancing creativity with analytical reasoning, educators can cultivate learners who are both inventive and reflective. Continued interdisciplinary research on incubation and insight will further illuminate the cognitive dynamics underlying non-routine problem-solving and guide evidence-based innovation in mathematics education.

REFERENCES

1. Abdulla, A. M., & Cramond, B. (2017). After the "Aha!": Understanding the cognitive mechanisms of incubation in creativity. Psychology of Aesthetics, Creativity, and the Arts, 11(3), 308–318. https://doi.org/10.1037/aca0000102
2. Abdulla, A. M., & Cramond, B. (2017). After the "Aha!": Understanding the cognitive mechanisms of incubation in creativity. Psychology of Aesthetics, Creativity, and the Arts, 11(3), 308–318. https://doi.org/10.1037/aca0000102
3. Allen, A. P., & Thomas, K. E. (2011). A dual process account of creative thinking. Creativity Research Journal, 23(2), 109–118.
4. American Psychological Association. (n.d.). Insight. In APA Dictionary of Psychology.https://dictionary.apa.org/insight
5. Beaty, R. E., Benedek, M., Silvia, P. J., & Schacter, D. L. (2016). Creative Cognition and Brain Network Dynamics. Trends in cognitive sciences, 20(2), 87–95. https://doi.org/10.1016/j.tics.2015.10.004
6. Bullard, E. (2024). Purposive sampling. EBSCO Research Starters: Social Sciences and Humanities.
7. https://www.ebsco.com/research-starters/social-sciences-and-humanities/purposivesampling#:~:text=Purposive%20sampling%2C%20also%20known%20as,characteristics%20relevant%2 0to%20their%20study
8. Camarista, G. G. (2016). The art of problem solving. Lorimar Publishing Incorporated.
9. Carlson, M. P., & Bloom, I. (2005). The cyclic nature of problem solving: An emergent multidimensional problem-solving framework. Educational Studies in Mathematics, 58(1), 45–75. https://doi.org/10.1007/s10649-005-0808-x
10. Danek, A. H., & Wiley, J. (2017). What about false insights? Deconstructing the Aha! experience along its multiple dimensions for correct and incorrect solutions separately. Frontiers in Psychology, 7, 2077. https://doi.org/10.3389/fpsyg.2016.02077
11. Gilhooly, K. J. (2016). Incubation and intuition in creative problem solving. Frontiers in Psychology, 7, 1076. https://doi.org/10.3389/fpsyg.2016.01076
12. Gilhooly, K. J., Georgiou, G., & Devery, U. (2013). Incubation and creativity: Do something different. Thinking and Reasoning, 19. https://doi.org/10.1080/13546783.2012.749812
13. Gilhooly, K. J., Georgiou, G. J., Garrison, J., Reston, J. D., & Sirota, M. (2012). Don't wait to incubate: Immediate versus delayed incubation in divergent thinking. Memory & Cognition, 40. https://doi.org/10.3758/s13421-012-0199-z
14. Hayes, A. (2024). Descriptive statistics. Investopedia.
15. https://www.investopedia.com/terms/d/descriptive_statistics.asp
16. Kohn, N., & Smith, S. M. (2020). Revisiting the incubation effect: Does taking a break really help? Journal of Creative Behavior, 54(2), 363–375. https://doi.org/10.1002/jocb.372
17. Kounios, J., & Beeman, M. (2015). The Eureka factor: Aha moments, creative insight, and the brain. Random House.
18. Kounios, J., & Beeman, M. (2020). The origins of insight: Cognitive and neural mechanisms of creative problem solving. Oxford University Press.

19. Kounios, J., & Beeman, M. (2020). The neuroscience of insight: What we know and how to proceed. Nature Reviews Neuroscience, 21(10), 1–14. https://doi.org/10.1038/s41583-020-0313-0
20. Krawczyk, D. C., Meyer, A., & Radvansky, G. A. (2022). The cognitive neuroscience of problemsolving and creativity. Annual Review of Psychology, 73, 421–447.
21. https://doi.org/10.1146/annurevpsych-020821-122911
22. Kuzle, A. (2013). Patterns of metacognitive behavior during mathematics problem solving in a dynamic geometry environment. International Electronic Journal of Mathematics Education, 8(1), 20–40.
23. https://www.iejme.com/download/patterns-of-metacognitive-behavior-during-mathematics-problemsolving-in-a-dynamic-geometry.pdf
24. Laukkonen, R. E., Ingledew, D. J., & Schooler, J. W. (2021). The neuroscience of insight: How introspection and awareness shape creative cognition. Neuroscience & Biobehavioral Reviews, 131, 1080–1095. https://doi.org/10.1016/j.neubiorev.2021.09.024
25. Leikin, R. (2019). Creativity and mathematics education: The state of the art. ZDM Mathematics Education, 51(3), 431–446. https://doi.org/10.1007/s11858-019-01045-1
26. McClenaghan, E. (2024). The Kruskal–Wallis test. Technology Networks. https://www.technologynetworks.com/informatics/articles/the-kruskal-wallis-test-370025
27. McClenaghan, E. (2024). Spearman Rank Correlation. Technology Networks.
28. https://www.technologynetworks.com/tn/articles/spearman-rank-correlation-385744
29. Metcalfe, J. (1986). Feeling of knowing in memory and problem solving. Journal of Experimental Psychology: Learning, Memory, and Cognition, 12(2), 288–294.
30. https://doi.org/10.1037/02787393.12.2.288
31. Mills, C., Raffaelli, Q., Irving, Z. C., Stan, D., Christoff, K., & Smallwood, J. (2018). Is an off-task mind a freely-moving mind? Examining the relationship between different dimensions of thought. Consciousness and Cognition, 58, 20–33. https://doi.org/10.1016/j.concog.2017.10.003
32. Nijstad, B. A., & De Dreu, C. K. W. (2020). Motivated information processing and creativity. Current Directions in Psychological Science, 29(6), 569–575. https://doi.org/10.1177/0963721420951592
33. Ormerod, T. (2009). Mechanisms underlying incubation in problem-solving: Evidence for unconscious cue assimilation. Proceedings of the Annual Meeting of the Cognitive Science Society.
34. Peñaloza, A. A., & Calvillo, D. P. (2012). Incubation provides relief from artificial fixation in problem solving.Creativity Research Journal, 24(4), 338-344. https://doi.org/10.1080/10400419.2012.730329
35. Poincaré, H. (1913). The foundations of science: Science and hypothesis, The value of science, Science and method. New York and Garrison, N. Y.: The Science Press.
36. Ritter, S. M., Dijksterhuis, A., & Van Baaren, R. B. (2021). Creativity in the wild: How incubation benefits problem-solving. Creativity Research Journal, 33(4), 415–427. https://doi.org/10.1080/10400419.2020.1866817
37. Schoenfeld, A. H. (2016). Learning to think mathematically: Problem-solving, metacognition, and sense making in mathematics. Routledge.
38. Schoenfeld, A. H. (2016). Mathematical thinking and problem solving (2nd ed.). Routledge.
39. Sio, U. N. (2007). The role of an incubation period in creative problem solving. Creativity Research Journal, 19. https://doi.org/10.1080/10400410701397453
40. Sio, U. N., & Ormerod, T. (2009). Does incubation enhance problem solving? A meta-analytic review. Psychological Bulletin, 135. https://doi.org/10.1037/a0014212
41. Sio, U. N., & Ormerod, T. C. (2009). Mechanisms underlying incubation in problem-solving: Evidence for unconscious cue assimilation. Proceedings of the Annual Meeting of the Cognitive Science Society.
42. Subedi, M. (2023). Use of mixed methods in social sciences research. Nepalese Journal of Development and Rural Studies, 20(1). https://doi.org/10.3126/njdrs.v20i01.64166
43. Wallas, G. (1926). The art of thought. J. Cape: London.
44. Zedelius, C. M., & Schooler, J. W. (2016). The richness of inner experience: Relating styles of daydreaming to creative processes. Frontiers in Psychology, 7, 661. https://doi.org/10.3389/fpsyg.2016.00661.