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Addressing the creativity gap: Teachers' implementation of mathematical creativity-promoting tasks before and after intervention

Marianthi Zioga [1]*, Despina Desli [1]

[1] School of Primary Education, Aristotle University of Thessaloniki Campus, Thessaloniki, GREECE
***Corresponding Author:** mizioga@eled.auth.gr

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ABSTRACT

Developing students' mathematical creativity constitutes a key objective in curricula worldwide. Although teachers recognize their key role in fostering mathematical creativity, research indicates a discrepancy between their beliefs and classroom practices–the "creativity gap". Professional development programs have enhanced teachers' theoretical understanding of mathematical creativity, but the extent to which this translates into classroom implementation remains unclear due to limited observational data. This qualitative study examines discrepancies between teachers' beliefs on mathematical creativity-promoting tasks and their actual classroom practices. Seven Greek in-service primary school teachers participated in interviews and classroom observation before and after attending a professional development program on mathematical creativity. Findings reveal significant gaps, particularly in designing and implementing open-ended tasks, fostering originality, and encouraging students to construct new knowledge. Even after the intervention, challenges persisted. The study underscores the need for targeted support in professional development programs to bridge the creativity gap effectively.

Keywords: classroom observation, creativity-promoting tasks, mathematical creativity, teachers' beliefs and practices, professional development program

INTRODUCTION

Mathematical creativity has gained increasing attention in mathematics education research, as it is recognized as a crucial 21st century skill (Pitta-Pantazi et al., 2022). According to Mann (2006), mathematical creativity extends beyond speed, accuracy, and algorithmic problem-solving; it involves generating novel solutions, identifying patterns, and approaching problems from multiple perspectives. In educational research, creativity in mathematics is typically assessed using four indices proposed by Guilford (1966) and Torrance (1967): fluency (the ability to generate multiple solutions to a problem), flexibility (the ability to approach problems from different perspectives), originality (the ability to produce unique or unconventional solutions), and elaboration (the ability to extend and refine ideas) (Leikin & Elgrably, 2022). Moreover, Cropley (2010) highlights that teaching for mathematical creativity is essential for fostering deep mathematical understanding, as well as for cultivating students' motivation and positive attitudes toward mathematics. Consequently, promoting creativity has become a central objective in curricula worldwide.

As Sánchez et al. (2022) explain, creativity can be taught in school settings through appropriate instruction, with teachers playing a crucial role in this process. Their beliefs and choices significantly influence students' opportunities for creativity development. However, research indicates that while many educators acknowledge the importance of creativity, and associate fluency, flexibility, and originality with its promotion (Levenson, 2013), their actual classroom practices often fail to align with these beliefs (Cropley, 2010; Lev-Zamir & Leikin, 2013; Zioga & Desli, 2023). This discrepancy, referred to by Gralewski (2016, p. 320) as the "*creativity gap*", underscores the need for professional development programs that enhance teachers' theoretical knowledge and awareness while enabling them to implement creativity-focused approaches into their mathematics lessons (Bicer et al., 2022). Existing studies on educational programs for mathematical creativity (Bicer et al., 2022; Levenson, 2015; Shriki, 2010) have yielded promising results, showing that participants' knowledge was enriched after the programs. However, these studies are limited in number and have primarily relied on self-reported data through interviews, questionnaires, and tests, without examining whether teachers successfully translate their newly acquired knowledge into actual teaching practices.

This study addresses this gap by investigating how in-service primary school teachers perceive and implement creativity-promoting mathematical tasks before and after participating in a six-week professional development program. By examining their beliefs, task choices, and the impact of the intervention, this research aims to bridge the gap between theoretical understanding and pedagogical practice in fostering mathematical creativity. Additionally, it contributes to the ongoing discussion on professional development programs that promote creativity in mathematics education.

LITERATURE REVIEW

Mathematical Creativity and Mathematical Creativity-Promoting Tasks

Although there is no single, universally accepted definition of mathematical creativity among educational researchers, various forms of mathematical thinking are widely recognized as characteristics of creative mathematical activity. These include the ability to generate multiple or novel solutions to a given task (Leikin & Elgrably, 2022), exhibit flexible problem-solving skills (Levenson et al., 2024), reconsider previously solved problems from new perspectives (Sriraman et al., 2011), and overcome fixations (Haylock, 1987, 1997). Additionally, as Silver (1997) highlights, student problem-posing and problem reformulation are key indicators of creativity in mathematics. Moreover, mathematical creativity is intrinsically connected to higher-order thinking skills, such as abstract reasoning–encompassing the identification of patterns and relationships as well as the recognition of connections between ideas–and the ability to generalize mathematical ideas (Sriraman, 2009).

As several researchers argue (e.g., Shriki, 2010; Silver, 1997), fostering mathematical creativity requires more than simply promoting Torrance's (1967) indices of creativity–fluency, flexibility, originality, and elaboration. It is equally important to encourage students to engage in mathematical activities in ways that mirror the work of professional mathematicians: formulating problems or questions driven by curiosity, making conjectures, attempting solutions, revising approaches, and ultimately resolving the problem. Hadamard's (1945, p. 104) insightful perspective on student creativity in mathematics remains highly relevant:

> "Between the work of the student who tries to solve a problem in geometry or algebra and a work of invention, one can say that there is only a difference of degree, a difference of level, both works being of a similar nature".

Describing mathematical creativity and identifying its characteristics is only the first step toward fostering it in school settings. Equally important is determining which types of mathematical tasks have the potential to develop students' creativity and encouraging teachers to integrate such tasks into their instruction. Several categories of creativity-promoting tasks have been identified in the literature. For instance, open-ended or multiple-solution tasks are often highlighted for their potential to cultivate students' fluency and originality, as they encourage the generation of multiple solutions and the exploration of less conventional answers (Klein & Leikin, 2020). Furthermore, since flexible thinking is a key characteristic of mathematical creativity, tasks that help students overcome fixations and stereotypical approaches are equally important (Haylock, 1987, 1997). In this regard, non-routine problems, which do not have a straightforward solution and require students to explore different heuristic strategies, are particularly valuable (Elia et al., 2009). Similarly, ill-structured problems, which resemble real-life situations, do not have a single correct solution, and can be approached from various perspectives, also support creative thinking (Silver, 1997). Tasks that involve identifying patterns or generalizing mathematical ideas further enhance creativity by fostering abstract and higher-order thinking skills (Assmus & Fritzlar, 2022; Hershkovitz et al., 2009). Additionally, as Silver (1997) emphasizes, tasks that can be extended (e.g., using the "what-if-not?" strategy) and those that involve student-directed problem-posing engage students in authentic mathematical activity and are particularly effective in fostering flexibility and mathematical creativity.

Teachers' Beliefs and Practices Regarding Mathematical Creativity

Students' engagement with creativity-promoting tasks largely depends on their teachers, who organize and shape the educational environment. As Levenson (2015) emphasizes, teachers assume multiple roles in fostering mathematical creativity. In addition to selecting tasks, they provide the mathematical background necessary for students to understand the mathematical reasoning behind algorithms and apply them flexibly. Teachers are also responsible for cultivating a learning environment where students feel encouraged and safe to express themselves and propose different ideas, solutions, and strategies.

In exploring teachers' views of creativity, Levenson (2013) examined the task features they associate with mathematical creativity. The participants in her study were primary and secondary school teachers, enrolled in a Master's degree program in Mathematics Education in Israel. The findings were encouraging, as many participants identified problems that promoted fluency, flexibility, and originality when asked to propose creativity-promoting tasks. However, the study did not examine how participants would implement these tasks in their classrooms.

In contrast, studies examining teachers' classroom practices (e.g., Lev-Zamir & Leikin, 2013; Zioga & Desli, 2025b) have revealed that teachers face challenges in fostering students' mathematical creativity, often neglecting creativity-promoting tasks and approaches. Although teachers across different countries view themselves as key factors in developing mathematical creativity among students (Leikin et al., 2013) and generally feel confident in this regard (Rubenstein et al., 2018), they are often inadequately prepared to achieve this goal (Bolden et al., 2010; Desli & Zioga, 2015) and tend to overlook many aspects of teaching for creativity (Bereczki & Karpati, 2018). More specifically, while teachers generally hold positive predispositions toward fostering mathematical creativity and attribute favorable traits to creative students (Aljughaiman & Mowrer-Reynolds, 2005), a discrepancy exists between their stated beliefs and enacted classroom practices. For instance, Lev-Zamir and Leikin (2013) observed two teachers during mathematics lessons. They found that only one teacher consistently promoted students' creativity in a way that aligned with her interview responses, while the other teacher exhibited a lack of flexibility in teaching, leading to a teacher-directed lesson that did not foster students' creativity. Furthermore, as Cropley (2010) explains, teachers often favor students who demonstrate speed and accuracy over those who exhibit personality traits associated with creativity, such as independent thinking and a critical attitude. This misalignment between beliefs and practices, also referred to as the "creativity gap" (Gralewski, 2016), underscores the need for professional development programs aimed at equipping teachers with strategies to effectively promote mathematical creativity (Bicer et al., 2022).

Previous Mathematical Creativity Intervention Studies

A limited number of studies on educational programs designed to foster mathematical creativity have been conducted to date. As anticipated, a substantial improvement was observed following the completion of these programs, both in participants' understanding of mathematical creativity and in their ability to design tasks that foster it. For instance, Shriki (2010) developed a university course for prospective secondary education mathematics teachers in Israel, encouraging them to "work like real mathematicians" by inventing new geometrical concepts, exploring their properties, and presenting their findings to their classmates. Shriki found that this process increased participants' awareness of the nature of mathematical creativity.

The participant in Levenson's (2015) study was an in-service secondary mathematics teacher who attended a graduate course on mathematical creativity in Israel. As Levenson (2015) notes, the participant's theoretical perceptions and knowledge of mathematical creativity expanded throughout the course. Moreover, the course had a positive impact on her ability to select creativity-promoting tasks, incorporating the concepts of fluency, flexibility, originality, overcoming fixations, and working like mathematicians.

Finally, Bicer et al. (2022) conducted an undergraduate course for pre-service primary school teachers in the USA. Participants in their study demonstrated significant improvement in both cognitive and affective outcomes and recognized mathematics as a creative discipline.

However, the studies mentioned above evaluated the impact of these educational courses using interviews, questionnaires, and tests. While these methods provided valuable insights into participants' perceptions of mathematical creativity, no one examined their actual classroom practices. The absence of observational data raises uncertainty about whether participants' enriched perceptions were successfully transferred into their teaching, effectively providing students with opportunities for creativity development. Given the "creativity gap", it is crucial to examine not only teachers' beliefs but also their classroom practices and the tasks they implement before and after participating in a similar program on mathematical creativity.

The Current Study

The current study has three overarching aims. First, we aimed to identify teachers' perspectives on creativity-promoting mathematical tasks, their enacted classroom practices, and their task selection before and after participating in a professional development program focused on mathematical creativity. Second, we aimed to examine whether a discrepancy exists between teachers' declarative beliefs and their actual classroom practices, aspiring to shed more light on the "creativity gap". By investigating teachers' evolving beliefs and instructional choices, this study provides valuable insights for future curriculum revisions and the design of professional development programs that more effectively address the "creativity gap". Third, we aimed to discuss the potential knowledge gained regarding the types of future mathematical creativity interventions needed to enhance all children's opportunities for mathematical creativity from an early age.

To achieve these objectives, this study aims to answer the following research questions:

1. How do teachers' stated beliefs about creativity-promoting mathematical tasks align with their enacted classroom practices before and after participating in a professional development program?
2. To what extent does the professional development program influence changes in teachers' instructional choices regarding mathematical creativity, and what challenges persist?

METHODOLOGY

Since this study aimed to investigate teachers' beliefs, enacted classroom practices, and their relationship, we employed a qualitative approach to gain deeper and more detailed insights into participants' perspectives and instructional choices. Furthermore, by focusing on seven teachers across seven different classrooms, we sought to capture a diverse and representative portrayal of their practices related to creativity.

Participants

Seven in-service primary school teachers participated in the study. They were selected based on their voluntary response to an open invitation addressed to all in-service primary school teachers in our county, inviting them to take part in a study incorporating an educational program on mathematical creativity. The participants represented diverse genders and mathematical backgrounds, taught across nearly the entire range of primary school grade levels, and contributed distinct personal perspectives to the study. As shown in **Table 1**, two participants taught grade 1, three taught grade 4, and two taught grade 5. Their teaching experience ranged from 8 to 30 years, with an average of 21 years. Their ages ranged from 32 to 55 years, with an average of 45.6 years. All participants had graduated from Greek pedagogical departments; one held a master's degree in language education, while two had pursued postgraduate studies in mathematics education. To ensure anonymity, pseudonyms were assigned to all participants. The study was conducted after obtaining the necessary ethics approval from the Ministry of Education.

Table 1. Participants' demographic and professional background

Participant (pseudonym)	Gender	Age	Years of experience	Postgraduate studies	Grade
Nicole	F	48	23	-	1
Georgia	F	47	22	-	1
Jason	M	43	18	Mathematics education	4
Helen	F	32	8	Language education	4
Peter	M	41	15	Mathematics education	4
Andrew	M	55	30	-	5
Paul	M	53	28	-	5

Research Design and Tools

The research data were collected using two complementary methods: classroom observations and participant interviews. According to Bryman (2017), employing multiple data collection methods enhances the validity of qualitative research. Additionally, comparing observational data with interview responses allows for an examination of the consistency between teachers' stated beliefs and their actual classroom practices.

The study was conducted in two phases. In the first phase, the first author observed each participant's classroom practices for four hours during mathematics lessons and conducted interviews with them. Following this, a six-week intervention program was implemented. After the completion of the intervention, the second phase of the study took place, which, similar to the first phase, involved classroom observations and interviews with the participants.

Classroom observation provides a more objective and comprehensive view of teachers' instructional approaches, task selection, and classroom practices. It is a valuable tool in educational research, as it allows for real-time data collection in participants' natural settings (Bell et al., 2018). This approach facilitates a deeper understanding of educational phenomena and enables researchers to identify details that may go unnoticed with other research tools. For the present study, a structured observation protocol was adopted. The protocol was designed to collect numerical data on the frequency and duration of specific characteristics (i.e., tasks and teaching approaches that promote mathematical creativity), allowing for a comparison of teaching practices before and after the intervention. Data were recorded in two ways:

(1) event sampling to note each observed characteristic and

(2) interval recording to document events chronologically at predetermined intervals (Cohen et al., 2007).

During the observation, the researcher briefly noted significant information and recorded additional relevant details immediately after each session. The semi-structured interview was selected to explore teachers' knowledge and views on mathematical creativity, as well as the practices that contribute to its cultivation in the classroom. To this end, it included questions focusing on the nature of mathematical creativity, teaching approaches that can enhance it, and tasks that promote it. Some of the questions posed to participants during the interview were: "*What is mathematical creativity?*", "*What kind of tasks foster students' mathematical creativity?*", "*What characteristics should a task have for you to consider it creativity-fostering?*", "*What criteria do you use to decide whether a mathematical outcome results from creative thinking?*", and "*What can a teacher do to foster mathematical creativity in the classroom?*".

The Intervention Program

The key ideas that guided the development of the intervention program were as follows:

1. Teachers are encouraged to examine the nature of mathematical creativity and the process of fostering creativity as a foundation for expanding their knowledge and shifting their perceptions of mathematical creativity.
2. Teachers engage in activities designed to help them construct deeper insights and develop rich, interconnected understandings of mathematical creativity and teaching mathematics.
3. Support is provided to guide the design of tasks that promote mathematical creativity.

The intervention was a six-week professional development program on mathematical creativity, attended by all participants and conducted by the first author of this study. Its objectives were:

(1) to enhance participants' knowledge and understanding of mathematical creativity and how it can be promoted in the classroom,

(2) to enable them to recognize, adapt, and design creativity-promoting tasks, and

(3) to transform their teaching practices to foster students' mathematical creativity more effectively.

The program was inspired by the educational courses of Shriki (2010) and Levenson (2015), which shared similar content and reported encouraging results.

In the following paragraphs, we briefly outline the content of the professional development program, which was conducted over six weekly sessions (for a more detailed description, see Zioga & Desli, 2025a). The first session introduced key concepts related to mathematical creativity and the teacher's role in cultivating it, with the researcher providing the theoretical background based on a review of the literature. The following four sessions focused on exploring different types of tasks that foster mathematical creativity.

Specifically, the second session presented the general characteristics of creativity-promoting tasks, with a focus on open-ended tasks. The third session highlighted tasks that help students overcome stereotypical thinking and examined the benefits of

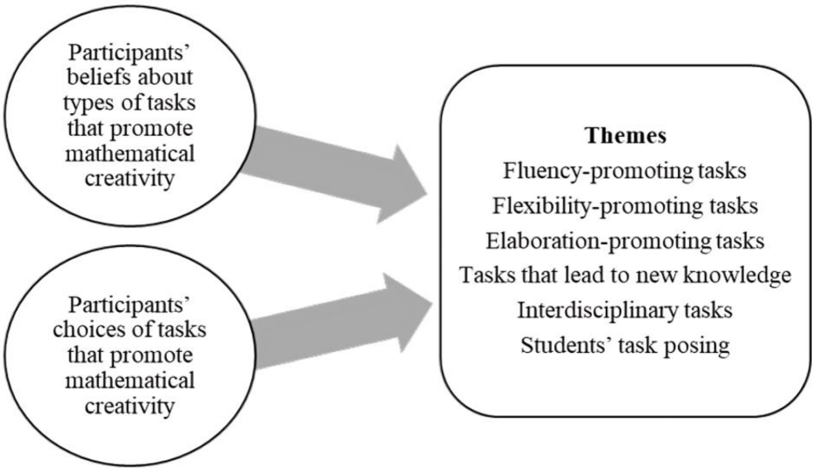

Figure 1. Categories and themes derived from the data analysis (Source: Authors' own elaboration)

non-routine problems. The fourth session introduced ill-structured problems, pattern problems, and tasks that lead to mathematical generalization. The fifth session addressed problems that could be extended with additional questions (e.g., using the "What-if …" strategy), student task-posing, and tasks aimed at the creation of new knowledge. Throughout the program, participants were actively engaged in commenting on and solving creativity-promoting tasks.

The sixth and final session focused on analyzing textbook tasks for their potential to cultivate mathematical creativity. Participants were asked to evaluate these tasks and modify them to enhance their capacity to promote creativity (e.g., by "opening" closed textbook tasks). However, despite their active participation throughout the program, the teachers became reluctant to modify existing tasks or design new ones, doing so only after continuous encouragement from the researcher. This reluctance can be attributed to a combination of time constraints and the participants' lack of experience in designing creativity-promoting tasks.

Data Analysis

The data collected during the research were analyzed using thematic analysis, a qualitative research method that identifies, examines, and interprets patterns within data. One of its core advantages is that it provides deep insights into participants' perceptions, behavior, and practices (Nowell et al., 2017). Specifically, thematic analysis systematically organizes and codes qualitative data (e.g., interview transcripts, open-ended survey responses, observational notes) to uncover recurring patterns of meaning (Lochmiller, 2021). These patterns, or themes, capture essential features of the data related to the research questions.

To generate the themes in our study, we followed the process described by Braun and Clarke (2006). First, we familiarized ourselves with the data (interview transcripts and observational notes). Next, we independently graded the data, demonstrating high inter-rater reliability (Cohen's kappa coefficient of .85), and generated initial codes. When there was a misalignment in our codes, we reviewed the data and discussed until we reached an agreement. We then identified themes by grouping codes into broader categories that reflect patterns of meaning. Subsequently, we reviewed and named the themes to ensure they accurately represented the data. Finally, we reported the results, incorporating extracts from classroom observations to illustrate each theme. The themes and categories are summarized in **Figure 1**.

RESULTS

Participants' Beliefs About Creativity-Promoting Tasks and Their Corresponding Teaching Practices Before the Intervention

Before participating in the educational program, as evident from **Table 2**, participants' perceptions of creativity-promoting tasks were relatively narrow, and their teaching choices were limited. Furthermore, significant discrepancies can be observed between their beliefs and actual practices. Specifically, participants primarily viewed open-ended tasks as creative, yet only 49 minutes were spent on such tasks during 28 hours of observation. Notably, none of the three participants who identified open-ended tasks as creative actually employed them in their teaching. Additionally, Peter, Georgia, and Paul emphasized students' task posing as a creative endeavor, but only Georgia and Andrew (who did not mention it in the interview) encouraged students to pose problems. Nicole and Georgia also explained that tasks promoting flexible thinking have the potential to cultivate mathematical creativity. However, prior to the intervention, almost no time was dedicated to flexibility-promoting tasks. It is worth noting that participants did not mention tasks that promote elaboration, originality, interdisciplinary connections, or opportunities for students to construct new knowledge. During classroom observation, only Jason devoted an entire teaching hour to a task that enabled students to actively create new knowledge. The absence of these task categories reveals a severe lack of opportunities for students to develop their mathematical creativity, as these categories constitute the core of mathematical creativity.

Table 2. Participants' beliefs and teaching practices related to creativity-promoting tasks before the intervention

Participants	Beliefs						Practices: Frequency of occurrence (time in minutes)					
	Fluency-promoting tasks	Flexibility-promoting tasks	Elaboration-promoting tasks	Tasks that lead to new knowledge	Interdisciplinary tasks	Students' task posing	Fluency-promoting tasks	Flexibility-promoting tasks	Elaboration-promoting tasks	Tasks that lead to new knowledge	Interdisciplinary tasks	Students' task posing
Jason	✓									1 (40)		
Andrew												1 (23)
Nicole		✓					3 (44)	1 (1)				
Helen	✓											
Peter	✓					✓						
Georgia		✓				✓						2 (30)
Paul						✓	1 (5)					

The misalignment between participants' views expressed in interviews and their actual teaching practices is evident in **Table 2** and becomes even more pronounced in **Table A1** in **Appendix A**. **Table A1** in **Appendix A** summarizes participants' beliefs about creativity-promoting tasks and their corresponding teaching practices, categorized by creativity trait and participant[1]. Regarding fluency development, as displayed in **Table A1** in **Appendix A**, Jason, Helen, and Peter recognized that multiple-solution tasks enhance creativity but did not implement them in their teaching, thus demonstrating *inconsistency*. In contrast, Paul, who did not mention the potential of open-ended tasks to foster creativity, assigned one such task from the textbook. However, the task required students to create eight fractions smaller than 1 using only specific given numbers, and Paul did not choose to "open" it further (for example, by encouraging students to find many different fractions smaller than one using any numbers). Moreover, throughout the rest of his teaching, he primarily focused on algorithmic thinking and did not encourage students to explore and discuss various solutions or ideas. Therefore, although he assigned one open-ended task, he is considered only *partly consistent in not promoting creativity*. On the other hand, Nicole, who did not mention open-ended tasks in her interview, frequently encouraged her students to search for different answers to the tasks she assigned. As a result, she is characterized as demonstrating positive inconsistency, as her teaching practices provided students with opportunities to develop their fluency.

Similar inconsistencies were evident in the development of flexibility, as shown in **Table A1** in **Appendix A**. For instance, Nicole focused more on "fun" activities rather than tasks that promote non-stereotypical thinking, which contradicted her statements in the interview. Furthermore, Andrew's teaching practices hindered the cultivation of students' creativity in one instance. Specifically, when a student suggested a different approach by converting decimal fractions to decimal numbers, Andrew interrupted her before she could fully articulate her thinking and asserted that there was a simpler solution. In doing so, he deprived the student of the opportunity to freely express her ideas, propose an alternative solution, and explore different representations of rational numbers.

Jason was the only participant who designed and implemented a mathematical task that provided students with the opportunity to construct new knowledge, despite not mentioning such tasks in his interview (see **Table A1** in **Appendix A**). Specifically, before the observation, Jason guided his students in organizing and conducting a survey on topics related to their hobbies, preferences, and everyday life. Students then analyzed the survey results using Microsoft Excel, creating graphs to represent data such as their favorite food, sport, number of siblings, height, and other personal information. During the observed lesson, students presented their findings in groups, and Jason connected their analyses and graphs to explain relevant statistical concepts, such as population, variables, and measures of central tendency. By the end of the presentations, students were able to answer any questions about the statistical concepts they had encountered.

Participants frequently discussed students' problem-posing as a creative endeavor during the interviews, as shown in **Table A1** in **Appendix A**. However, this approach was not effectively reflected in their classroom practices. On the rare occasions when participants encouraged students to pose problems, the process was highly teacher-directed, resulting in stereotypical problems. This left little room for students to take initiative, hypothesize, explore flexible approaches, or engage in problem-solving and reformulation. Notably, Andrew guided students to pose a specific problem that he had predetermined as the "correct" problem, despite the potential for students to pose diverse, including open-ended, problems. Overall, participants' practices regarding problem-posing were not conducive to promoting mathematical creativity.

As noted earlier, participants neither mentioned nor implemented originality-promoting, elaboration-promoting, or interdisciplinary tasks before the intervention. This absence reflects their limited perceptions of mathematical creativity and explains the lack of tables addressing these creativity traits.

Participants' Beliefs About Creativity-Promoting Tasks and Their Corresponding Teaching Practices After the Intervention

The overview of participants' beliefs about tasks that can promote students' mathematical creativity and their corresponding teaching practices after the intervention, is presented in **Table 3**. Notably, in contrast to the pre-intervention period, all seven participants now recognize the potential of open-ended tasks to foster student creativity. However, despite a threefold increase

[1] **Table A1** in **Appendix A** includes only participants who mentioned the specific creativity trait in their interviews or incorporated these tasks in their teaching.

Table 3. Participants' beliefs and teaching practices related to creativity-promoting tasks after the intervention

	Beliefs						Practices: Frequency of occurrence (time in minutes)					
Participants	**Fluency-promoting tasks**	**Flexibility-promoting tasks**	**Elaboration-promoting tasks**	**Tasks that lead to new knowledge**	**Interdisciplinary tasks**	**Students' task posing**	**Fluency-promoting tasks**	**Flexibility-promoting tasks**	**Elaboration-promoting tasks**	**Tasks that lead to new knowledge**	**Interdisciplinary tasks**	**Students' task posing**
Jason	✓	✓						5 (47)		3 (60)	1 (40)	
Andrew	✓							1 (20)				4 (37)
Nicole	✓	✓					2 (61)	2 (16)	1 (22)			
Helen	✓	✓					3 (68)					
Peter	✓	✓				✓		3 (83)				
Georgia	✓	✓				✓	1 (15)		1 (14)	2 (63)		1 (28)
Paul	✓	✓				✓		1 (8)				

in the time dedicated to such tasks (144 minutes), only three participants actually implemented them in their teaching. Similarly, nearly all participants acknowledged the creativity-enhancing potential of flexibility-promoting tasks, and five of them incorporated these tasks, dedicating substantial instructional time (174 minutes). Participants' beliefs and practices regarding student task-posing remained largely unchanged from the pre-intervention phase, with three participants identifying it as a creativity-promoting approach and two actually employing it in their teaching. Interestingly, while none of the participants mentioned elaboration-focused tasks in their interviews, two participants, Nicole and Georgia, utilized such tasks during classroom observations. Similarly, although participants did not consider tasks leading to new knowledge as creativity-promoting, Jason and Georgia implemented five such tasks, devoting a total of 123 minutes. Additionally, Jason devoted an entire lesson to an interdisciplinary task, despite the fact that no participants had mentioned such tasks. These findings suggest that participants' classroom practices have become more enriched, offering greater opportunities to cultivate mathematical creativity.

Despite improvements in participants' classroom practices compared to the pre-intervention period, discrepancies between their beliefs and practices remained evident, as shown in **Table B1** in **Appendix B**. For instance, regarding tasks that promote fluency (**Table B1** in **Appendix B**), although Jason stated in his interview that "*creativity-promoting tasks are open-ended tasks with multiple solutions*", he did not actually implement any such tasks, thus being characterized as inconsistent in promoting fluency. In contrast, Helen, who was consistent in fostering fluency, also recognized the creativity-enhancing potential of open-ended tasks and implemented numerous such tasks, including asking students to design various shapes with the same perimeter or area. Similarly, Nicole organized a game that encouraged students to find different ways to create specific sums using more than two addends and implemented an open-ended task on number arrangement, prompting students to find as many solutions as possible.

Some inconsistencies were also observed regarding the development of flexibility, as displayed in **Table B1** in **Appendix B**. For example, Helen and Georgia described the potential of ill-structured tasks or tasks that allow for student initiative in their interviews, but they did not incorporate such tasks during their teaching. However, other participants were consistent in promoting flexibility. Jason, for instance, referred to tasks that "*encourage students to develop multiple solution strategies*" and, in practice, assigned numerous non-routine tasks that required students to explore different solution approaches (e.g., "*Use various tangram pieces to create oblique parallelograms with a given area*"). Similarly, Peter provided opportunities for flexibility development by implementing one non-routine problem and two ill-structured problems (e.g., "*Design a house's floor plan with an area of 100 sq. meters*").

Interestingly, as shown in **Table B1** in **Appendix B**, while elaboration was not discussed by participants during the interviews, Nicole and Georgia incorporated tasks that promoted generalization and abstract thinking, respectively. Similarly, **Table B1** in **Appendix B** displays that, although the interviews did not identify the development of new knowledge as a creativity-enhancing process, Jason and Georgia designed active learning experiences that enabled students to construct new knowledge (e.g., "*Discover how to calculate the area of an oblique parallelogram*"). Furthermore, Jason implemented an interdisciplinary task, where he described Eratosthenes' experiment to measure the earth's circumference and had students actively participate in recreating part of it on the vernal equinox (see **Table B1** in **Appendix B**). In all these instances, the teachers' classroom practices demonstrated a discrepancy with their stated beliefs and were characterized as *demonstrating a positive inconsistency*.

Table B1 in **Appendix B** illustrates that participants' teaching practices related to student task-posing remained largely unchanged from the pre-intervention phase. Only one participant, Georgia, demonstrated consistency between her beliefs and practices. She acknowledged that encouraging students to extend tasks or pose new questions can foster mathematical creativity and applied this approach in her teaching by having students pose addition or subtraction problems related to their interests. In contrast, Andrew asked students to pose problems on fraction addition and multiplication but directed the process, guiding students at every step. Similarly, Peter and Paul discussed the benefits of student task-posing, they did not incorporate this practice into their observed lessons and were therefore considered inconsistent.

It is worth noting that, as before, participants did not mention originality-promoting tasks in their interviews after the intervention, nor did they incorporate these tasks into their teaching.

DISCUSSION

The analysis of the results revealed major discrepancies between participants' declarative beliefs and their teaching practices, particularly prior to the intervention. This finding aligns with previous research on the creativity gap, which identifies an inconsistency between teachers' beliefs about creativity and their actual classroom practices (Lev-Zamir & Leikin, 2013).

Prior to the intervention, participants' views on mathematical creativity and tasks that promote it were quite limited, as they overlooked key aspects such as originality and the construction of new knowledge - a common finding in previous studies (Bolden et al., 2010; Desli & Zioga, 2015). Furthermore, their stated beliefs about the potential of open-ended tasks, flexibility-promoting tasks, and students' task-posing to foster mathematical creativity were not reflected in their teaching. Aside from Jason organizing an activity that led to new knowledge and Nicole employing three open-ended tasks, participants generally did not implement the creativity-enhancing practices discussed in their interviews. This discrepancy between beliefs and practices may stem from several factors, including teachers' lack of knowledge and confidence in implementing creativity-directed tasks, the influence of traditional school culture, and the challenges of balancing creativity-enhancing practices with curricular demands and standardized assessments (Bicer et al., 2022; Lev-Zamir & Leikin, 2013). Following the intervention, participants' perceptions of creativity showed modest enrichment, with more teachers recognizing the potential of open-ended tasks and flexibility-promoting activities to cultivate creativity. However, they continued to focus on certain aspects of creativity, largely overlooking originality and active knowledge construction. As for their teaching practices, the results indicate a general improvement, with more time devoted to creativity-promoting tasks and a greater alignment between their beliefs and actions.

Despite the intervention, some participants continued to exhibit inconsistencies between their stated beliefs about fostering creativity and their actual teaching practices. This was particularly evident in the implementation of tasks designed to promote fluency, which all participants mentioned in the interviews but only three actually implemented. As Rubenstein et al. (2018) note, these discrepancies could be attributed to environmental or personal barriers, such as prevailing school culture, time constraints, standardized curricula, and the difficulty teachers face in changing long-established practices. Additionally, while participants recognized the value of open-ended tasks in fostering creativity, they found it challenging to design such tasks or transform closed textbook problems into open-ended ones. This finding, coupled with the lack of creativity-promoting tasks in mathematics textbooks, underscores the need to enrich school resources with tasks that nurture creative thinking. Furthermore, it suggests that future professional development programs should focus more on actively engaging participants in designing creativity-promoting tasks, for example, by incorporating more hands-on workshops.

Another key finding is that, in most cases, both before and after the intervention, problem-posing was not effectively utilized to promote creativity development. While some participants acknowledged the value of student task-posing, their implementation of this approach remained teacher-directed and limited to algorithmic tasks. As a result, they failed to provide students with the opportunity and autonomy needed to engage in creative mathematical thinking, formulate questions based on their own interests, and generate hypotheses to test, as Silver (1997) suggests. This highlights an important consideration for future teacher education programs.

Interestingly, on many occasions, participants who had not mentioned certain types of creativity-promoting tasks during the interviews actually employed them in their teaching, thus demonstrating a positive inconsistency that favored their practices. These tasks included those that foster elaboration, the creation of new knowledge, and interdisciplinary connections. The discrepancy between the participants' beliefs and practices, with practices often surpassing their stated beliefs, can be attributed to several factors. First, the intervention's emphasis on implementing creativity-promoting tasks and strategies may have enriched some of their teaching choices beyond their stated beliefs. Additionally, the opportunity to observe and reflect on their own teaching during the intervention may have encouraged them to adopt certain creativity-enhancing approaches. Furthermore, their participation in the intervention likely boosted their confidence in applying creativity-enhancing practices.

Previous studies (e.g., Lev-Zamir & Leikin, 2013; Zioga & Desli, 2023) have suggested that teachers' mathematical background can influence their ability to foster students' mathematical creativity. Indeed, in the current study, the two participants with a master's degree in mathematics education demonstrated significant improvement in their creativity-promoting practices. More specifically, Jason and Peter devoted more time to creativity-promoting tasks after the intervention, employing a variety of such tasks. From another perspective, however, this outcome could also be attributed to their personal interest in mathematics. A similar development was observed in Georgia's and Nicole's practices. While they may not have as strong a mathematical background, their teaching styles are less teacher-directed and more focused on active student participation, perhaps due to their experience teaching Grade 1. This student-oriented approach appears to favor practices that enhance creativity. The participants whose practices exhibited the least or no improvement were Paul and Andrew, who predominantly endorsed traditional, teacher-directed approaches and did not provide opportunities for active student participation. Thus, the results suggest that participants' pedagogical content knowledge and teaching style may influence their ability to promote mathematical creativity, a finding that is also supported by Lev-Zamir and Leikin (2013).

Implications of the Study

This study has several important implications. First, by examining the discrepancies between in-service teachers' stated beliefs and enacted classroom practices on mathematical creativity, it highlights the urgent need to bridge the creativity gap in mathematics education. This insight could be valuable for educational policy makers and textbook writers, encouraging the inclusion of more creativity-promoting tasks and teaching approaches in future curricula revisions. Additionally, the findings emphasize the need for future professional development programs to not only enhance teachers' theoretical understanding of creativity but, more importantly, to provide ample opportunities for designing creativity-promoting tasks and support teachers in translating their knowledge into classroom practice. Finally, the findings suggest that teachers' mathematical background, personal interests, and teaching styles may play a crucial role in their ability to foster students' mathematical creativity.

Limitations and Future Directions

The study's findings should be interpreted with caution, as the limited number of participants restricts the ability to generalize the results. Nevertheless, the small sample size allowed for in-depth classroom observations and a closer examination of actual teaching practices, which would not have been feasible with a larger number of participants. Additionally, the fact that participants taught at different grade levels may have influenced their teaching styles. Future research could explore the classroom practices of teachers instructing the same grade level and compare their approaches to teaching the same mathematical concepts, with a particular focus on fostering mathematical creativity.

CONCLUSION

This study examines in-service teachers' beliefs and classroom practices regarding mathematical creativity, highlighting the gap between the two. The educational intervention had a positive impact on participants, resulting in an increased implementation of creativity-fostering tasks and a reduction in discrepancies between stated beliefs and classroom practices. However, certain inconsistencies persist, particularly in the design and use of open-ended tasks. The findings emphasize the need for future professional development programs that support teachers in translating their theoretical understanding of creativity into the design and implementation of creativity-promoting tasks, as well as in adopting practices that foster students' mathematical creativity.

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APPENDIX A

Table A1. Summary of similarities and inconsistencies between participants' stated beliefs and practices regarding …

Participants	Beliefs	Observed practices	Comments
… fluency-promoting tasks before the intervention			
Jason	*Tasks that have more than one solution (foster creativity)*	Does not employ tasks that promote fluency.	Inconsistent
Nicole	-	Asks students to create different groups of cubes that sum to a total of 6 cubes (and later to 8 cubes). Asks students to find multiple numbers that are either smaller or larger than certain given numbers.	Demonstrating a positive inconsistency
Helen	*Open-ended tasks are creative*	Does not employ tasks that promote fluency.	Inconsistent
Peter	*Open-ended tasks (promote creativity), i.e., tasks with more than one correct solution*	Does not employ tasks that promote fluency.	Inconsistent
Paul	-	Assigns an open-ended textbook task requiring students to create fractions smaller than 1 using specific given numbers.	Partly consistent in not promoting creativity. He uses only one open-ended textbook task, while the rest of his teaching is algorithmic-oriented.
… flexibility-promoting tasks before the intervention			
Andrew	-	Discourages a student from explaining her solution strategy (converting decimal fractions to decimal numbers) to solve a task. States that "*there is a simpler solution*" and interrupts her.	Inhibits creativity
Nicole	*(Problems that represent) addition situations beyond their stereotypical form*	Encourages students to find different estimation strategies in a subitizing task.	Partly consistent. She uses only one flexibility-promoting task. The rest of her teaching focuses mainly on "fun" activities.
Georgia	*(Creativity-promoting tasks) allow for multiple solution strategies (Also, tasks) may have incomplete elements that students can attempt to incorporate*.	Does not implement tasks that promote flexibility.	Inconsistent
… constructing new knowledge before the intervention			
Jason	-	Students organize, conduct, and present a survey. They analyze the results in Excel and create graphs. With Jason's guidance, they understand complex statistical concepts (e.g., population, variables, measures of central tendency).	Demonstrating a positive inconsistency. Grade 4 students actively engage with and correctly respond to questions about statistical concepts on a surprisingly high level.
… students' task-posing before the intervention			
Andrew	-	Asks students to pose a problem using all the given written on the board. Guides students to pose a specific "correct" problem, although it is possible to pose different problems, including open-ended ones.	Consistent in not promoting creativity
Peter	*Posing open-ended tasks by students is a creative endeavor*.	Does not encourage students to pose tasks.	Inconsistent
Georgia	*(A creativity-promoting task) asks students to create a problem using their imagination. Each student can create a unique problem with different givens*.	Asks students to pose additional problems using numbers up to 10. Encourages them to use everyday items as given and draw them.	Consistent. However, the proposed problems are stereotypical, similar, and not creativity-promoting.
Paul	*Posing problems for their classmates to solve is a creativity-promoting task. This is creative; everyone can express themselves. Posing problems means creating problems*.	Does not encourage students to pose tasks.	Inconsistent

APPENDIX B

Table B1. Summary of similarities and inconsistencies between participants' stated beliefs and practices regarding …

Participants	Beliefs	Observed practices	Comments
… fluency-promoting tasks after the intervention			
Jason	*Creativity-promoting tasks are open-ended tasks with multiple solutions*	Does not employ tasks that promote fluency.	Inconsistent
Andrew	*(A task is creative if) each student is able to propose a different solution based on their individual experiences.*	Does not employ tasks that promote fluency.	Inconsistent
Nicole	*Tasks that have many solutions and foster divergent thinking (are creative)*	Asks students in the form of a game to find different ways to create specific sums using more than two additives. Encourages students to find as many solutions as possible to an open-ended task regarding number arrangement.	Consistent
Helen	*Open-ended tasks with multiple solutions allow each student to propose a solution that aligns with their way of thinking.*	Asks students to design multiple shapes with the same perimeter. Asks students to design multiple shapes with the same area. Asks students to paint 1/10 of a square decimeter in various ways.	Consistent
Peter	*Tasks that require students to find multiple solutions, open-ended tasks in general, or tasks that propose one solution and ask students to find alternative ones.*	Does not employ tasks that promote fluency.	Inconsistent
Georgia	*Tasks that have multiple solutions*	Encourages students to find multiple responses to an open-ended task (create different routes on a squared paper).	Consistent
Paul	*Creativity-promoting tasks are more time-consuming, as students need more time to think and generate multiple answers.*	Does not employ tasks that promote fluency.	Inconsistent
… flexibility-promoting tasks after the intervention			
Jason	*… tasks that encourage students to develop multiple solution strategies, including those that may not initially appear mathematical but can be solved using appropriate mathematical strategies.*	Assigns numerous non-routine tasks requiring students to explore different solution strategies (e.g., use various tangram pieces to create oblique parallelograms with a given area). Encourages students to perform mental calculations by employing a variety of mental calculation strategies.	Consistent
Andrew	-	Assigns one non-routine problem from a mathematical contest and discusses two solution strategies.	Partly consistent in not promoting creativity. He uses only one non-routine task and spends most of the time discussing the algorithmic solution.
Nicole	*They (creativity-promoting tasks) do not have a specific, single solution path or algorithm that students must follow; they allow students to explore different paths and use various methods to reach a solution.*	Uses different representations, including manipulatives, to describe numbers.	Partly consistent. Different representations promote flexibility, but she does not use non-routine or non-algorithmic tasks.
Helen	*Tasks that allow students to take the initiative … that are not closed.*	Does not employ tasks that promote flexibility.	Inconsistent
Peter	*Logic problems that involve many givens and questions require a gradual elimination of solutions to reach the final solution … Tasks that can be solved in various ways.*	Assigns two ill-structured problems (e.g., designing a house's floor plan with an area of 100 sq. meters) and one non-routine problem.	Consistent
… elaboration-promoting tasks after the intervention			
Nicole	-	Assigns a task that leads to generalization	Demonstrating a positive inconsistency
Georgia	-	Assigns a task that promotes abstract thinking (students represent their actual position in three-dimensional space on squared paper).	Demonstrating a positive inconsistency
… constructing new knowledge, after the intervention			
Jason	-	Assigns three tasks that lead to new knowledge (e.g., calculate the area of an oblique parallelogram).	Demonstrating a positive inconsistency
Georgia	-	Designs an active learning experience focused on spatial orientation in organized environments.	Demonstrating a positive inconsistency

Table B1 (Continued). Summary of similarities and inconsistencies between participants' stated beliefs and practices regarding …

Participants	Beliefs	Observed practices	Comments
… interdisciplinary tasks, after the intervention			
Jason	-	Describes Eratosthenes' experiment to measure the Earth's circumference and reenacts part of it with active student participation. Students measure the length of a wooden stick and its shadow at noon on the vernal equinox, using trigonometric tables to calculate the earth's circumference.	Demonstrating a positive inconsistency
… students' task-posing, after the intervention			
Andrew	-	Encourages students on multiple occasions to pose stereotypical, teacher-directed problems (e.g., problems solvable through fraction addition and multiplication).	Consistent (in not promoting creativity)
Peter	*Students should be encouraged to extend problems, explore ways to modify or incorporate new givens, and find solutions.*	Does not encourage students to pose tasks.	Inconsistent
Georgia	*Creativity-promoting tasks typically allow children to extend them and make them more interesting … By extending (the task), students can also pose their own questions. Even a closed task, which does not promote creativity, can lead to another task.*	She asks students to work in pairs and pose addition or subtraction problems to be solved in the classroom. She often extends their problems and poses new questions that reflect their interests.	Consistent
Paul	*Apart from tasks that present a question, some do not ask anything; they allow students to pose their own questions. They provide certain givens and require students to create a problem.*	Does not encourage students to pose tasks.	Inconsistent