Journal of Honai Math, 9(1), 99-120, April 2026
https:/doi.org/10.30862/jhm.v9i1.1059

Mathematical creativity in algebraic tasks of South African secondary school mathematics textbooks

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Received: 13 October 2025 | Revised: 12 March 2026 | Accepted: 16 April 2026

Abstract

Fostering mathematical creativity is widely recognized as a fundamental objective of mathematics education because it enhances learners' problem-solving capabilities and contributes to the achievement of Sustainable Development Goal 4 (Quality Education). However, limited empirical research has explored the extent to which mathematics textbooks support the development of mathematical creativity. This study examined how algebraic tasks in two South African secondary school mathematics textbook series promote mathematical creativity. Six textbooks were analyzed using quantitative content analysis, and independent samples t-tests were employed to determine whether significant differences existed between the textbook series. The analysis was guided by Ramelan and Wijaya's framework of mathematical creativity, which comprises four dimensions: fluency, flexibility, elaboration, and originality. The findings revealed that the two textbook series fostered these dimensions to varying degrees. One series demonstrated a stronger emphasis on elaboration and originality, whereas the other provided greater support for fluency and flexibility. Overall, the textbooks moderately promoted fluency but offered limited opportunities for learners to develop flexibility, elaboration, and originality, suggesting that algebraic tasks generally provide insufficient support for the cultivation of mathematical creativity. Furthermore, the independent samples t-test indicated no statistically significant difference between the two-textbook series in their overall promotion of mathematical creativity. These findings highlight a misalignment between curriculum aspirations and textbook implementation and underscore the need for richer, open-ended algebraic tasks that better support creative mathematical thinking.

Keywords: Algebra, mathematical creativity, mathematical tasks, quality education, secondary mathematics textbooks

Introduction

Mathematical creativity has attracted increasing attention within mathematics education research and has been examined from diverse theoretical perspectives, including developmental, psychometric, economic, cognitive, problem-solving, and expertise-oriented frameworks (Hernandez-Torrano & Ibrayeva, 2020). While these perspectives have enriched understandings of mathematical creativity, they have also contributed to the absence of a universally accepted definition of the construct (Aktas, 2016; Chamberlin & Moon, 2005; Hernandez-Torrano & Ibrayeva, 2020; Nadjafikhah et al., 2012; Sriraman, 2005; Yazgan-Sağ & Emre-Akdoğan, 2016). Consequently, scholars have emphasized the need for conceptualizations of mathematical creativity that are grounded in robust understandings of both mathematical knowledge and mathematical practice (Riling, 2020).

Broadly conceived, mathematical creativity refers to an individual's capacity to generate novel, meaningful, and mathematically valuable ideas, solutions, representations, or products by drawing upon existing mathematical knowledge. Such creativity may manifest in various forms, including concepts, procedures, methods, conjectures, explanations, solutions, and mathematical reasoning (Scott-Barrett et al., 2023). The development of mathematical creativity is closely linked to learners' conceptual and procedural understanding of mathematics (Hafizi & Kamarudin, 2020). Learners must be able to represent mathematical situations in multiple ways, including through symbols, formulae, tables, graphs, diagrams, and relationships among mathematical objects (Ubah & Ogbonnaya, 2021; Zhang et al., 2020). Consistent with this view, Schoevers et al. (2018) and Huang et al. (2017) found that mathematical competence is a strong predictor of mathematical creativity, suggesting that richer mathematical understanding provides learners with greater opportunities to engage creatively with mathematical ideas and problems.

The literature further distinguishes mathematical creativity according to the context in which it occurs. Sriraman (2005) argues that mathematical creativity is observable at both professional and school levels. At the professional level, creativity involves producing original mathematical work that extends existing knowledge and contributes meaningfully to the discipline. It also includes posing novel questions capable of generating new mathematical insights. Within Kaufman & Beghetto's (2009) creativity framework, such forms of creativity may be categorized as Pro-C creativity, representing expert-level creative achievement, and Big-C creativity, referring to groundbreaking contributions that transform disciplines, cultures, or societies.

In contrast, school-level mathematical creativity concerns learners' generation of unusual, insightful, and personally meaningful approaches to mathematical situations (Sriraman, 2005). Such creativity may be demonstrated through the formulation of original questions, the development of non-routine solution strategies, or the reinterpretation of familiar problems from new perspectives. Within Kaufman & Beghetto's (2009) framework, school-level creativity is reflected in Mini-C creativity, which involves personally meaningful insights and interpretations, and Small-C creativity, which encompasses everyday creative actions undertaken by non-experts. Given its relevance to classroom teaching and learning, the present study focuses specifically on mathematical creativity at the school level.

Several scholars have proposed definitions that illuminate the nature of school-based mathematical creativity. Nadjafikhah et al. (2012) define mathematical creativity as the process through which learners identify, combine, and select meaningful mathematical ideas to solve unfamiliar problems. This perspective highlights learners' capacity to discover previously unrecognized relationships among mathematical concepts and facts. Similarly, Chamberlin & Moon (2005) conceptualize mathematical creativity as learners' ability to generate innovative and useful solutions to authentic or simulated real-world problems through mathematical modelling. Creativity, from this perspective, becomes evident when learners employ non-standard approaches to solve problems that could otherwise be addressed using conventional procedures. Extending this argument, Bicer (2021) and Nadjafikhah et al. (2012) contend that mathematical creativity is not limited to producing entirely new ideas or solutions. Rather, it also involves learners discovering mathematical relationships, patterns, or structures that are novel to them, even if such discoveries are already known within the broader mathematical community.

A similar emphasis on learners' active engagement with mathematical thinking is evident in the work of Huang et al. (2017), Aktas (2016), and Yazgan-Sağ & Emre-Akdoğan (2016), who argue that mathematical creativity is demonstrated when learners identify and define problems independently, formulate original problems, generate multiple solution strategies, invent formulas, develop new approaches to problem solving, and justify their reasoning. Likewise, Yerushalmy (2009) characterizes mathematical creativity as the ability to conjecture, explore uncertainty, adopt personal perspectives, and engage in inquiry, argumentation, explanation, and refutation. Collectively, these perspectives suggest that mathematical creativity extends beyond the production of correct answers to encompass flexible, divergent, and reflective forms of mathematical thinking.

Despite its importance, evaluating mathematical creativity remains challenging. Zhang et al. (2020) note that the assessment of creative mathematical products requires judgments regarding both novelty and usefulness. However, perceptions of what constitutes a creative mathematical product may vary across individuals, cultures, and contexts. A mathematical idea considered innovative in one setting may be viewed as commonplace in another. Consequently, assessments of mathematical creativity should be sensitive to contextual and cultural factors that shape interpretations of originality and value.

The significance of mathematical creativity extends beyond mathematics classrooms. Creativity is increasingly recognized as an essential competency for navigating contemporary social, economic, and technological environments (Huang et al., 2017). Research suggests that creativity enables learners to reason effectively, connect ideas, interpret complex situations, and make sense of the world around them (Hafizi & Kamarudin, 2020). Furthermore, creativity supports adaptability in response to rapid societal change and prepares learners for future educational and occupational demands (Lu & Kaiser, 2022; OECD, 2019; Scott-Barrett et al., 2023). According to the OECD (2019), creativity contributes to the development of metacognitive, interpersonal, and problem-solving competencies while simultaneously supporting academic achievement, identity formation, civic engagement, and career success. Hafizi & Kamarudin (2020) further argue that creativity is particularly important during the transition from secondary to tertiary education, where learners are expected to integrate, apply, and synthesize knowledge acquired across different educational stages.

Within mathematics education, creativity enriches teaching and learning by enabling learners and teachers to approach mathematical tasks from multiple perspectives and to generate alternative interpretations and solutions (Klein & Leikin, 2020; Miranda & Mamede, 2022; Yazgan-Sağ & Emre-Akdoğan, 2016). Through such engagement, learners develop deeper understandings of mathematical concepts and processes while contributing to the advancement of mathematical knowledge. Beyond educational outcomes, creativity has been associated with broader societal benefits, including economic development, innovation, industrial productivity, self-actualization, and social well-being (Hafizi & Kamarudin, 2020; Hernandez-Torrano & Ibrayeva, 2020). As Tubb et al. (2020) observe, creativity has become a highly valued competency in the twenty-first-century workforce, where employers increasingly seek individuals capable of addressing complex and unfamiliar problems. Consequently, fostering mathematical creativity represents an important educational objective with implications extending far beyond school mathematics.

The South African education system explicitly recognizes the importance of creativity in preparing learners to identify and solve problems and to make informed decisions through critical and creative thinking (Department of Basic Education, 2011). Importantly, mathematical creativity is not an innate characteristic restricted to exceptionally gifted learners but rather a capacity that can be nurtured and developed among all learners (Riling, 2020). Mathematics classrooms therefore provide an important context for cultivating creativity. Teachers play a central role in this process by creating environments characterized by openness, trust, collaboration, questioning, exploration, and productive engagement with mistakes (Aktas, 2016). Research further suggests that mathematical creativity can be enhanced through appropriate pedagogical approaches and carefully designed mathematical tasks (Abdul Hamid & Kamarudin, 2021; Bicer et al., 2021; Khalid et al., 2020; Yazgan-Sağ & Emre-Akdoğan, 2016). Such approaches move beyond rigid algorithmic procedures and instead promote flexible, divergent, and exploratory forms of mathematical thinking (Nadjafikhah et al., 2012). Collaborative problem-solving, project-based learning, and learner-centered instructional approaches have therefore been recommended as effective means of fostering creativity in mathematics classrooms (Khalid et al., 2020).

Among the various factors influencing learners' opportunities to engage in mathematical creativity, mathematical tasks occupy a particularly important position because they shape the nature and quality of learners' mathematical experiences. Tasks determine the extent to which learners are encouraged to explore multiple solution pathways, justify their reasoning, formulate conjectures, and engage in divergent thinking. Consequently, the creative potential of mathematics classrooms is closely linked to the characteristics of the tasks that learners encounter.

Despite the recognized importance of mathematical creativity, research examining its promotion within secondary school mathematics remains relatively limited (Schoevers et al., 2018). Furthermore, Gan (2023) highlights a notable lack of research investigating the extent to which mathematical tasks themselves foster creativity. Existing studies have frequently employed tasks merely as research instruments rather than examining their role as vehicles for developing creative mathematical thinking. This gap is particularly significant given the central role of textbooks in shaping mathematics teaching and learning experiences in many educational contexts.

Against this background, the present study investigates the extent to which algebraic tasks in South African secondary school mathematics textbooks promote mathematical creativity. By examining textbook tasks through the lens of mathematical creativity, the study contributes directly to Sustainable Development Goal 4 (Quality Education), which emphasizes the development of creativity, critical thinking, and problem-solving competencies. It also contributes indirectly to Sustainable Development Goals 8 (Decent Work and Economic Growth) and 9 (Industry, Innovation and Infrastructure) through its focus on fostering innovation-oriented capabilities among learners. Specifically, the study addresses the following research questions:

1. To what extent do algebraic tasks in the textbook series promote mathematical creativity?
2. Which components of mathematical creativity are promoted by the algebraic tasks in the textbook series?
3. Are there statistically significant differences between the textbook series in their promotion of mathematical creativity?

Theoretical Background

Mathematical creativity is widely conceptualized as a multidimensional construct comprising four interrelated components: fluency, flexibility, originality, and elaboration (Bales & Estomo, 2022; Czarnocha, 2014; Hernandez-Torrano & Ibrayeva, 2020; Joklitschke et al., 2022; Scott-Barrett et al., 2023). These components provide a useful framework for understanding how learners generate, develop, and communicate mathematical ideas. Fluency refers to the ability to produce multiple appropriate responses or alternative solutions to a mathematical task. Flexibility extends this notion by emphasizing the capacity to generate solutions, strategies, or questions that belong to different categories or perspectives. Originality concerns the production of uncommon, novel, or statistically infrequent ideas, questions, or solution methods, whereas elaboration refers to the ability to develop, refine, extend, or enrich mathematical ideas and procedures. Collectively, these components capture the diverse ways in which learners engage creatively with mathematical problems and tasks.

Beyond these observable components, mathematical creativity has also been conceptualized as the outcome of a complex set of cognitive processes. Childs et al. (2022) and Huang et al. (2017) argue that mathematical creativity emerges through the interaction of divergent thinking, convergent thinking, mathematical modelling, representational flexibility, insight generation, and the ability to establish connections among mathematical facts and concepts. Divergent thinking enables learners to generate multiple possible ideas, strategies, or solutions and is closely associated with the dimensions of fluency, flexibility, and originality. In contrast, convergent thinking supports the evaluation, refinement, and validation of these ideas, thereby contributing to the development of mathematically meaningful outcomes. Furthermore, learners engage creatively when they move between different representations, identify underlying structures, and establish meaningful relationships among concepts. From this perspective, mathematical creativity is not merely reflected in the production of novel solutions but also in the cognitive processes through which learners explore, evaluate, and develop mathematical ideas.s

Given the importance of these processes, mathematics education researchers have increasingly emphasized the role of mathematical tasks in fostering creativity. Tasks designed to promote mathematical creativity are typically characterized as open-ended, non-routine, ill-structured, authentic, and cognitively demanding (Aktas, 2016; Bicer, 2021; Bicer et al., 2021; Khalid et al., 2020; Levenson, 2013; Zhang et al., 2020). Such tasks frequently involve problem posing, multiple solution pathways, real-world contexts, dynamic exploration, communication, visualization, technological tools, and connections among mathematical ideas. Exposure to these task characteristics provides learners with opportunities to investigate alternative approaches, justify their reasoning, formulate original solutions, and engage in flexible mathematical thinking. Consequently, the nature of the tasks presented to learners plays a critical role in shaping opportunities for mathematical creativity.

Recognizing the significance of task design, several researchers have developed analytical frameworks for identifying and evaluating the extent to which mathematical tasks foster creativity (Bicer, 2021; Childs et al., 2022; Levenson, 2013; Munro, 2019; Ramelan & Wijaya, 2019). These frameworks provide theoretical and practical criteria for examining creativity within mathematical activities by focusing on task characteristics, creativity indicators, and the specific dimensions of mathematical creativity that tasks are likely to promote. Such frameworks have become increasingly valuable for evaluating instructional materials, including mathematics textbooks, because they enable systematic analysis of learners' opportunities to engage in creative mathematical thinking.

The present study adopts the framework developed by Ramelan & Wijaya (2019). This framework was selected because it explicitly focuses on the four core dimensions of mathematical creativity fluency, flexibility, originality, and elaboration and provides clear criteria for analyzing the extent to which mathematical tasks promote each dimension. Moreover, its emphasis on task characteristics makes it particularly suitable for textbook analysis, where the objective is to examine how curricular materials create opportunities for learners to engage in creative mathematical activity. Using this framework, the algebraic tasks contained in the selected textbook series were analyzed according to the level at which they promoted each component of mathematical creativity. The operational indicators used in the analysis are presented in Table 1.

Table 1. Framework for assessing and coding creativity-directed algebraic tasks (Adapted from Ramelan & Wijaya, 2019)

Component	Indicators	Explanation	Example	Comment
Fluency	Tasks have many solutions. Tasks promote the use of multiple representations (e.g., algebraic, verbal, graphic, numeric)	The task has at least two different answers or solutions. The instructions for the task can motivate learners to find more than one solution.	(i). Write three different expressions of $8x^2$ using the laws of exponents. (ii). What are the x intercepts $y = x^2 + x - 6$	(i). $8x^2$ can be expressed as $(2x)^3, 2^3x^3, 4 \times (2x^2)$, etc. (ii). This can be solved algebr5aically or graphically.
Flexibility	Tasks can be solved in many ways. (e.g., Algorithmic, non-algorithmic, brainstorming, list, trial- and-error, working backwards, modelling)	Problems can be solved in at least two ways. The instructions for the task do not limit the methods that can be used to solve it.	Solve $4(x - 2) = 20$.	This can be solved by: (i) expanding the bracket and solving for x (ii) Dividing both sides by 4 first. (iii) Use graphical representation, $y = 4(x - 2)$ and reading off the value of x when $y = 20$.
Elaboration	Tasks can motivate learners to develop and add or elaborate on ideas.	The task can motivate learners to add more detail to an object, idea, or situation. Task instructions can motivate learners to elaborate on their solutions.	Explain how the pattern $3, 6, 11, 18, 2$ explain in detail how the pattern grows and derive the n^{th} term.	The learner identifies that the common difference $(3, 5, 7, 9)$ shows a quadratic growth pattern and derives the nth term $(Tn) = n^2 + 2$.
Originality	The tasks promote the	The task can motivate learners to	Create a quadratic	An example is: the pattern $0, 3, 8, 15,$

Component	Indicators	Explanation	Example	Comment
	generalisation of mathematical ideas. Tasks promote the generation of unexpected	generalize and generate unexpected or unique mathematical ideas and solutions. The task instructions encourage learners to generalize and generate unique ideas and solutions.	number pattern and describe its rule.	$24, \ldots$ adds $3, 5, 7, 9, \ldots$ successively. The rule is: $Tn = n^2 - 1$.

Methods

This study employed a mixed-methods content analysis design incorporating both qualitative and quantitative approaches to investigate the extent to which algebraic tasks in South African secondary school mathematics textbooks promote mathematical creativity. The qualitative component focused on identifying and categorizing the creativity-promoting characteristics of algebraic tasks, whereas the quantitative component examined the frequency and distribution of mathematical creativity indicators and enabled statistical comparisons across textbook series.

The study focused on algebra because of its foundational role in the broader domain of mathematics and its importance in developing learners' mathematical reasoning, abstraction, modelling, and problem-solving abilities (AL-Rababaha et al., 2022; Chandler et al., 2023). Algebraic modelling provides learners with opportunities to engage with non-routine and real-world problems, thereby creating conditions that can foster mathematical creativity. Consequently, the analysis concentrated on algebraic content areas included in the South African Grades 9–11 mathematics curriculum, namely exponents, algebraic expressions, equations and inequalities, and number patterns

Textbook Sample

The study analyzed six Department of Basic Education-approved learner textbooks drawn from two secondary school mathematics textbook series. To ensure anonymity and facilitate comparison, the textbooks were coded as 9A, 10A, 11A, 9B, 10B, and 11B, where the letter denotes the textbook series and the numerical value represents the grade level. All algebraic tasks contained within these textbooks constituted the unit of analysis.

Analytical Framework and Coding Procedures

The algebraic tasks were analyzed using the mathematical creativity framework developed by Ramelan & Wijaya (2019) (Table 1). The framework was selected because it explicitly operationalizes the four dimensions of mathematical creativity fluency, flexibility, originality, and elaboration and provides clear indicators for identifying the extent to which mathematical tasks promote each dimension. Prior to the analysis, both authors familiarized themselves extensively with the framework and reviewed representative examples of tasks associated with each creativity component. The clarity and specificity of the framework facilitated consistent identification and differentiation of creativity indicators across textbook tasks.

Each algebraic task was initially classified according to whether it promoted mathematical creativity. Tasks identified as promoting at least one component of mathematical creativity were categorized as creativity-directed tasks and assigned a code of 1, whereas tasks that did not promote any component of mathematical creativity were categorized as non-creativity-directed tasks and assigned a code of 0. This binary coding procedure enabled the calculation of overall creativity-promotion scores for each textbook.

Subsequently, all creativity-directed tasks were examined in greater detail to identify the specific creativity components they promoted. The coding of fluency, flexibility, originality, and elaboration followed the operational definitions presented in Table 1. Because a single task could promote more than one component of mathematical creativity, multiple codes were assigned where appropriate. The frequency and relative distribution of each creativity component were then compared across textbook series and grade levels.

Data Analysis

Descriptive statistical analyses were conducted to determine the extent to which mathematical creativity was promoted within the textbook series. Mean creativity-promotion scores were calculated for each textbook and textbook series. To facilitate interpretation, the promotion levels were classified as weak, moderate, or strong according to the criteria presented in Table 2.

Table 2. Mathematical creativity promotion levels

Classification	Mean score ($\bar{x}$)	Classification
Weak	$0 \leq \bar{x} < 0.4$	1
Medium	$0.4 \leq \bar{x} < 0.6$	2
Strong	$0.6 \leq \bar{x} < 1$	3

The classification thresholds were informed by educational assessment standards commonly used in educational contexts, where scores below 40% are generally interpreted as indicating low proficiency or achievement below the minimum expected competency level, scores between 40% and 59% indicate moderate achievement, and scores of 60% or higher indicate satisfactory or strong achievement (Department of Basic Education, 2011; Owan et al., 2023).

In addition to descriptive analyses, independent samples t-tests were performed to determine whether statistically significant differences existed between the two textbooks series regarding their overall promotion of mathematical creativity. Comparative analyses were also conducted to examine variations in the promotion of individual creativity components across textbooks and grade levels.

All quantitative analyses were performed using SPSS. The mean scores and frequencies of the creativity components were calculated to provide a comprehensive picture of how mathematical creativity was represented within the algebraic tasks.

Trustworthiness and Coding Consistency

To enhance the credibility and dependability of the findings, particular attention was given to coding accuracy and consistency throughout the analysis process. The researchers maintained accurate records of all task frequencies and systematically applied the coding criteria derived from the analytical framework. Furthermore, the use of clearly defined operational indicators for each creativity component supported consistent classification of tasks and strengthened the validity of the findings.

Results and Discussion

The analysis commenced with an examination of the distribution of algebraic tasks across the six textbooks. As presented in Table 3, both textbook series contained substantial numbers of worked examples and learner exercises related to algebra. Across Grades 9–11, Series A comprised 289 worked examples and 1,774 learner exercises, whereas Series B contained 343 worked examples and 2,162 learner exercises. Thus, Series B provided a larger number of algebraic learning opportunities than Series A. However, the quantity of tasks alone does not necessarily reflect the extent to which learners are afforded opportunities to engage in creative mathematical thinking. Consequently, the subsequent analysis focused on the extent to which the algebraic tasks promoted the four dimensions of mathematical creativity.

Algebraic tasks in textbooks

Table 3 presents the distribution of algebraic tasks across the two-textbook series.

Table 3. Distribution of algebraic tasks in the textbooks

	Worked Examples		Exercises	
	Textbook Series			
Grade	A	B	A	B
9	86	125	593	1007
10	122	141	726	725
11	81	77	455	430
Total	289	343	1774	2162

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Mathematical Creativity in Grade 9 Textbooks

A total of 679 algebraic tasks were identified in textbook 9A, comprising 86 worked examples and 593 learner exercises. Of these tasks, 360 promoted fluency, 165 promoted flexibility, 53 promoted elaboration, and 72 promoted originalities. Textbook 9B contained 1,132 algebraic tasks, of which 601 promoted fluency, 174 promoted flexibility, 73 promoted elaboration, and 33 promoted originality (Table 4).

Table 4. Frequency of the components of creativity in the textbooks

Grade	Fluency		Flexibility		Elaboration		Originality	
	Textbook Series							
	A	B	A	B	A	B	A	B
9	360	601	165	174	53	73	72	33
10	457	441	167	248	86	30	54	14
11	343	374	169	260	68	95	16	13
Total	1160	1416	501	682	207	198	142	60

The examples presented in Figure 1 illustrate the nature of creativity-promoting tasks in the Grade 9 textbooks. The task from textbook 9A provides opportunities for fluency and elaboration by encouraging learners to generate alternative solution methods and justify the reasoning underpinning their approaches. By contrast, the task from textbook 9B promotes elaboration and originality through investigation, explanation, rule construction, and the development of a flowchart. Such features require learners to extend their mathematical thinking beyond routine procedural application.

Jason argues that the equations $2x^2 = 8x$ and $2x^2 = 8$ only each have one solution. His reasoning is as follows:

$2x^2 = 8x$ $\qquad$ $2x^2 = 8$

$\therefore \frac{2x^2}{2x} = \frac{8x}{2x}$ $\qquad$ $\therefore x^2 = 4$

$\therefore x = \sqrt{4}$

$\therefore x = 4$ $\qquad$ $\therefore x = 2$

Explain why Jason is incorrect.

Textbook 9A

a) Take a square of paper that is 8 cm long and 8 cm wide. Cut it in half and measure the area, then cut the half into another half and measure the area again. Continue to cut it into halves and measure the area each time. What do you notice? Explain this in a few sentences, and write down the pattern and the rule. (5)

b) Design a flow chart that represents the above pattern. (4)

Textbook 9B

Figure 1. Tasks from Textbooks 9A and 9B that promote creativity

Mathematical Creativity in Grade 10 Textbooks

Textbook 10A contained 848 algebraic tasks, including 122 worked examples and 726 learner exercises. Among these tasks, 457 promoted fluency, 167 promoted flexibility, 86 promoted elaboration, and 54 promoted originalities. Textbook 10B contained 866 algebraic tasks, consisting of 141 worked examples and 725 learner exercises. Of these tasks, 441 promoted fluency, 248 promoted flexibility, 30 promoted elaboration, and 14 promoted originality (Table 4).

The illustrative tasks presented in Figure 2 demonstrate differing emphases in creativity promotion. The task selected from textbook 10A primarily promotes originality by requiring learners to generate novel mathematical responses, whereas the task from textbook 10B emphasizes elaboration by encouraging learners to extend, justify, and communicate their mathematical reasoning.

If you add the fractions $2\frac{2}{7}$ and $1\frac{7}{9}$ you get the answer $4\frac{4}{63}$.

If you now multiply these fractions you also get the answer $4\frac{4}{63}$.

(a) Write down two other pairs of fractions which work like the two above.

(b) Determine a general rule to generate more of these fraction pairs. (Hint: use the letters a and b in your conjecture)

Textbook 10A

For all the questions below, $k \in \mathbb{Z}$.

1. Show that:
   a) $k^2 + k$ is even
   b) $k^2 - k$ is even
   c) $k^3 - k$ is divisible by 6.
2. Explain why you cannot predict whether $k^4 - 1$ will be even or odd.

Textbook 10B

Figure 2. Examples of tasks from 10A and 10B that promote creativity

Mathematical Creativity in Grade 11 Textbooks

A total of 536 algebraic tasks were analyzed in textbook 11A, including 81 worked examples and 455 learner exercises. Among these tasks, 343 promoted fluency, 169 promoted flexibility, 68 promoted elaboration, and 16 promoted originalities. Textbook 11B contained 507 algebraic tasks, comprising 77 worked examples and 430 learner exercises. Of these, 374 promoted fluency, 260 promoted flexibility, 95 promoted elaboration, and 13 promoted originalities (Table 4).

Examples of creativity-promoting tasks from the Grade 11 textbooks are presented in Figure 3. The task from textbook 11A promoted all four dimensions of mathematical creativity by requiring learners to model a contextual situation using algebraic expressions and equations, solve the resulting equations, and justify each stage of their reasoning. The task from textbook 11B promoted fluency, flexibility, and elaboration by encouraging learners to employ multiple solution approaches and explain their mathematical thinking. Compared with the lower grades, these tasks appear to provide richer opportunities for reasoning, modelling, and strategic problem solving.

Kevin travels 360 km from his farm to an agricultural fair. He only returns after dark and his average speed on the return journey is 10 km/h less. It took him 30 minutes longer to travel back. Determine his average speed on the journey to the fair.

Textbook 11A

Consider the equation: $2x^2 - 5x = 9$

4.1 Without solving for x, discuss the nature of the roots.

4.2 Solve for x, correct to two decimal places, by:

4.2.1 completing the square

4.2.2 using the quadratic formula.

Textbook 11B

Figure 3. Examples of tasks from 11A and 11B that promote creativity

Frequency of the Components of Mathematical Creativity

Table 4 summarizes the frequency with which each component of mathematical creativity was promoted across the two-textbook series. Fluency emerged as the most frequently promoted component in both series, with totals of 1,160 tasks in Series A and 1,416 tasks in Series B. Flexibility was promoted less frequently but remained the second most common creativity component, appearing in 501 tasks in Series A and 682 tasks in Series B. Considerably fewer tasks promoted elaboration (207 in Series A and 198 in Series B) or originality (142 in Series A and 60 in Series B). These findings suggest that opportunities to generate multiple responses were more common than opportunities to develop detailed reasoning or produce original mathematical ideas.

Frequency of the Components of Mathematical Creativity

Table 5 presents the mean promotion scores for each dimension of mathematical creativity across grades and textbook series. A consistent pattern emerged across both series, with fluency receiving the highest levels of promotion and originality receiving the lowest. For fluency, both series demonstrated moderate levels of promotion across all grades. The two series obtained identical scores in Grade 9 (0.53), while Series A recorded a marginally higher score in Grade 10 (0.54) than Series B (0.51). In Grade 11, however, Series B demonstrated substantially stronger promotion of fluency (0.74) than Series A (0.64), suggesting a greater emphasis on generating multiple solution pathways at the senior secondary level.

Table 5. Mathematical creativity promotion levels of the textbooks' algebraic tasks

Mathematical creativity component	Grade	Textbook Series	
		A	B
Fluency	9	0.53	0.53
	10	0.54	0.51
	11	0.64	0.74

Flexibility	9	0.24	0.15
	10	0.20	0.29
	11	0.32	0.51
Elaboration	9	0.08	0.06
	10	0.10	0.03
	11	0.13	0.19
Originality	9	0.11	0.03
	10	0.06	0.02
	11	0.03	0.03
Mathematical creativity per grade	9	0.24	0.19
	10	0.23	0.21
	11	0.28	0.37
Overall mathematical creativity per series		0.24	0.26

The promotion of flexibility differed across grades. Although Series A recorded higher flexibility scores in Grade 9 (0.24 compared with 0.15), Series B surpassed Series A in Grades 10 and 11, achieving scores of 0.29 and 0.51, respectively. This pattern suggests that Series B increasingly encourages learners to explore diverse representations and solution strategies as they progress through the curriculum. A similar trend was observed for elaboration. Series A demonstrated stronger promotion in Grades 9 and 10, whereas Series B recorded higher scores in Grade 11. These findings indicate that the senior-level tasks in Series B place greater emphasis on explanation, justification, and the development of mathematical arguments.

Originality recorded the lowest promotion scores across both textbook series. Although Series A consistently achieved higher scores than Series B in Grades 9 and 10, the overall levels remained low. In Grade 11, both series recorded identical originality scores (0.03), indicating limited opportunities for learners to generate novel mathematical ideas or unconventional solution methods. When the overall mathematical creativity scores were examined, Series A demonstrated slightly stronger promotion in Grades 9 and 10, whereas Series B achieved a notably higher score in Grade 11. Nevertheless, the overall mathematical creativity scores for the two series were very similar (Series A = 0.24; Series B = 0.26). According to the classification framework adopted in this study, both series therefore exhibited weak overall promotion of mathematical creativity.

Comparison of Mathematical Creativity Promotion Between the Textbook Series

To determine whether the observed differences between the two textbook series were statistically significant, an independent samples t-test was conducted. The results of Levene's test indicated homogeneity of variance ($F = 0.859$, $p = .364$), satisfying the assumption of equal variances. The independent samples t-test revealed no statistically significant difference in the overall promotion of mathematical creativity between Series A and Series B, $t(22) = -0.096$, $p = .924$ presented in Table 6. Although the two textbook series differed in the relative emphasis placed on specific dimensions of creativity, particularly originality and flexibility, the statistical analysis indicates that their overall capacity to promote mathematical creativity through algebraic tasks was comparable.

Table 6. Independent samples t-test comparing the mathematical creativity promotion of the textbooks

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	f	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
MC_ Score	Equal variances assumed	.859	.364	-.096	22	.462	.924	-.00917	.09512	-.20644	.18811
	Equal variances not assumed			-.096	21.338	462	.924	-.00917	.09512	-.20680	.18846

Discussion

This study investigated the extent to which algebraic tasks in two South African secondary school mathematics textbook series promote mathematical creativity. The findings revealed that although both textbook series incorporated tasks that fostered aspects of mathematical creativity, the overall level of creativity promotion remained weak across Grades 9–11. Furthermore, no statistically significant difference was found between the two-textbook series in their overall promotion of mathematical creativity. These findings raise important questions regarding the extent to which mathematics textbooks support the curricular aspiration of developing learners who can think creatively, reason critically, and solve problems effectively.

A prominent finding of the study is the uneven distribution of the four components of mathematical creativity. Across both textbook series, fluency emerged as the most frequently promoted component, whereas flexibility, elaboration, and originality received substantially less attention. According to Ramelan & Wijaya's (2019) framework, mathematical creativity encompasses not only the generation of multiple responses but also the production of diverse, refined, and original mathematical ideas. Consequently, the relatively stronger promotion of fluency cannot be interpreted as evidence that learners are being provided with comprehensive opportunities to develop mathematical creativity. Rather, the findings suggest that learners are more frequently encouraged to produce multiple answers within familiar procedural structures than to engage in exploratory reasoning, alternative representations, or innovative mathematical thinking.

The predominance of fluency-oriented tasks is consistent with previous research indicating that mathematical tasks often emphasize the generation of multiple responses while providing fewer opportunities for flexibility and originality (Bales & Estomo, 2022; Schoevers et al., 2018). One possible explanation is that fluency is comparatively easier to embed within conventional textbook exercises. Learners can be asked to generate several examples, complete repetitive calculations, or apply familiar procedures to a range of similar situations without requiring substantial modifications to traditional textbook formats. In contrast, tasks designed to foster flexibility and originality often require open-ended structures, multiple solution pathways, or opportunities for learners to formulate and investigate their own mathematical ideas, features that are less commonly represented in school textbooks.

The limited promotion of flexibility identified in this study is particularly noteworthy because flexibility is central to meaningful mathematical problem solving. Flexibility enables learners to move between representations, consider alternative strategies, and adapt their thinking when confronted with unfamiliar situations (Huang et al., 2017). The relatively low flexibility scores suggest that many of the analyzed tasks may encourage procedural execution rather than strategic decision-making. As a result, learners may have fewer opportunities to develop adaptive expertise, which is increasingly recognized as a critical goal of contemporary mathematics education. This finding is concerning given that algebra, by its nature, offers rich opportunities for exploring multiple representations, patterns, generalizations, and solution methods.

Similarly, the low levels of elaboration observed across both textbook series suggest limited opportunities for learners to explain, justify, and extend their mathematical reasoning. Elaboration plays a critical role in the development of mathematical understanding because it requires learners to make their thinking visible, communicate relationships among concepts, and construct coherent mathematical arguments. Tasks requiring explanation and justification not only contribute to creativity but also support the development of mathematical reasoning and proof-related competencies. The relatively weak emphasis on elaboration may therefore limit learners' opportunities to engage in deeper forms of mathematical sense-making.

Perhaps the most striking finding concerns the consistently low promotion of originality. Across both textbook series, originality received the lowest scores and appeared only infrequently within algebraic tasks. Opportunities for learners to formulate conjectures, generate novel solution methods, develop unique mathematical models, or produce original mathematical ideas were scarce. This finding aligns with the observations of Klein & Leikin (2020) and Miranda & Mamede (2022), who argue that mathematics textbooks frequently rely on closed and routine exercises that constrain creative exploration. From a curricular perspective, the limited emphasis on originality is problematic because originality represents a defining feature of mathematical creativity and is essential for fostering innovation-oriented competencies among learners.

The findings also reveal important variations across grade levels. Series A demonstrated relatively stronger promotion of originality and elaboration in Grades 9 and 10, whereas Series B showed greater promotion of fluency and flexibility in Grade 11. These patterns may reflect differences in textbook design philosophies and assumptions about learners' mathematical development. Series A appears to provide more opportunities for exploratory engagement during the early years of secondary schooling, while Series B increasingly incorporates tasks that require multiple strategies and representations at the senior level. Nevertheless, despite these differences, both textbook series ultimately exhibited similarly low overall levels of creativity promotion, as evidenced by the non-significant results of the independent samples t-test.

The comparatively stronger promotion of mathematical creativity observed in Grade 11, particularly within Series B, may be attributable to the nature of advanced algebraic content. Senior secondary algebra often requires learners to engage in abstraction, modelling, interpretation, and generalization, all of which have the potential to support flexibility and elaboration. However, the persistence of low originality scores even at this level suggests that increased cognitive demand does not necessarily translate into greater opportunities for creative mathematical production. Learners may still be expected to follow predetermined procedures rather than generate genuinely novel approaches to mathematical problems.

From a theoretical perspective, the findings support conceptualizations of mathematical creativity that emphasize the importance of divergent thinking and open-ended problem solving (Childs et al., 2022; Huang et al., 2017). Tasks that encourage learners to explore multiple representations, justify reasoning, formulate conjectures, and generalize mathematical relationships create opportunities for creative mathematical activity. However, the relatively limited presence of such tasks in the analyzed textbooks suggests that learners may have restricted opportunities to engage in the cognitive processes associated with creativity. Consequently, the development of mathematical creativity may depend heavily on teachers' pedagogical decisions rather than being systematically embedded within the instructional materials themselves.

The findings further reinforce the argument that textbook tasks play a crucial role in shaping learners' opportunities to learn mathematics creatively (Bicer et al., 2021; Levenson, 2013). In many South African classrooms, textbooks serve as primary instructional resources and strongly influence both classroom practices and assessment expectations. Consequently, the nature of textbook tasks affects not only what learners learn but also how they learn. When tasks are predominantly routine, procedural, and closed-ended, opportunities for inquiry, exploration, and creative engagement become limited. Conversely, tasks that are open-ended, authentic, investigative, and capable of supporting multiple solution pathways are more likely to foster creativity, autonomy, and deeper mathematical understanding.

The findings also reveal a potential disconnect between curriculum intentions and textbook implementation. The South African Curriculum and Assessment Policy Statement (CAPS) emphasizes the development of critical and creative thinking, problem solving, and independent reasoning (Department of Basic Education, 2011). However, the relatively weak promotion of flexibility, elaboration, and originality identified in the analyzed textbooks suggests that these curricular goals may not be fully reflected in the tasks provided to learners. This misalignment may reduce opportunities for learners to develop the competencies envisioned by the curriculum and may limit the realization of broader educational objectives associated with creativity and innovation.

Beyond the South African context, the findings have implications for Sustainable Development Goal 4 (Quality Education), which advocates for the development of knowledge, skills, creativity, and problem-solving abilities necessary for meaningful participation in society. Mathematical creativity is increasingly recognized as a key competency for lifelong learning, innovation, and participation in knowledge-based economies. Therefore, enhancing opportunities for mathematical creativity within textbooks may contribute not only to improved mathematics learning outcomes but also to broader educational and societal goals. Moreover, by fostering learners' capacities for innovation, adaptability, and creative problem solving, mathematics education can indirectly contribute to Sustainable Development Goals 8 (Decent Work and Economic Growth) and 9 (Industry, Innovation and Infrastructure).

Taken together, the findings suggest that opportunities for mathematical creativity in the analyzed textbooks remain limited and unevenly distributed across creativity dimensions and grade levels. Although both textbook series provide some opportunities for creative engagement, particularly through fluency-oriented tasks, they offer considerably fewer opportunities for learners to develop flexibility, elaboration, and originality. To better align textbook design with contemporary curricular goals and theoretical perspectives on creativity, textbook authors and curriculum developers should incorporate a greater proportion of open-ended, non-routine, investigative, and multiple-solution algebraic tasks. Such tasks would provide richer opportunities for learners to explore mathematical ideas, justify reasoning, generate original solutions, and engage more fully in creative mathematical activity.

Conclusion

This study investigated the extent to which algebraic tasks in two South African secondary school mathematics textbook series promote mathematical creativity. Drawing on Ramelan & Wijaya's (2019) framework, which conceptualizes mathematical creativity in terms of fluency, flexibility, elaboration, and originality, the findings revealed that both textbook series demonstrated weak overall promotion of mathematical creativity across Grades 9–11. Although opportunities for creative engagement were present, the promotion of creativity was unevenly distributed across its components. Fluency emerged as the most frequently promoted dimension, whereas flexibility, elaboration, and originality received considerably less emphasis. Furthermore, the independent samples t-test indicated no statistically significant difference between the two-textbook series in their overall promotion of mathematical creativity, suggesting that both series provide comparable opportunities for creative mathematical engagement.

The findings reveal a notable discrepancy between the aspirations of the South African mathematics curriculum and the opportunities for creativity embedded within the analyzed instructional materials. While the curriculum emphasizes creativity, critical thinking, reasoning, and problem solving, the algebraic tasks contained in the textbooks were predominantly routine, closed-ended, and procedurally oriented. Consequently, learners are more likely to engage in the reproduction and application of established procedures than in exploration, justification, conjecturing, modelling, or the generation of original mathematical ideas. Such an emphasis may limit opportunities for learners to develop the deeper conceptual understanding, adaptive expertise, and creative competencies required for meaningful participation in contemporary society.

From a theoretical perspective, the findings reinforce the argument that mathematical creativity extends beyond the production of multiple responses and requires opportunities for learners to engage in flexible, elaborative, and original mathematical thinking. The relatively low representation of these dimensions suggests that learners may have restricted opportunities to participate in the divergent and exploratory processes that underpin creative mathematical activity. Given the influential role of textbooks in shaping classroom practices and learners' opportunities to learn, enhancing the creativity-promoting potential of textbook tasks represents an important avenue for improving mathematics education.

Moreover, the findings contribute to ongoing discussions concerning the role of mathematics education in advancing Sustainable Development Goal 4 (Quality Education). By providing learners with opportunities to think creatively, reason critically, and solve unfamiliar problems, mathematics classrooms can contribute to the development of competencies necessary for lifelong learning, innovation, and participation in knowledge-based economies. Strengthening mathematical creativity within instructional materials may therefore support not only improved mathematics learning outcomes but also broader educational and societal goals related to innovation, adaptability, and sustainable development.

Implications and Future Research

The findings have important implications for curriculum development, textbook design, classroom practice, and future research. First, textbook authors and curriculum developers should incorporate a greater proportion of open-ended, non-routine, investigative, and real-world algebraic tasks that explicitly promote fluency, flexibility, elaboration, and originality. Such tasks should encourage learners to explore multiple solution pathways, justify and communicate their reasoning, formulate conjectures, model real-life situations mathematically, and reflect critically on their problem-solving processes. Greater attention should also be paid to achieving a balanced representation of the four dimensions of mathematical creativity, rather than emphasizing fluency alone.

Second, the findings underscore the importance of supporting teachers in recognizing and fostering mathematical creativity during classroom instruction. Even when textbooks contain predominantly routine exercises, teachers can adapt, extend, and transform such tasks into creativity-oriented learning opportunities through purposeful questioning, multiple-solution approaches, mathematical discussions, and exploratory activities. Professional development initiatives should therefore equip teachers with the pedagogical knowledge and strategies necessary to cultivate mathematical creativity in diverse classroom contexts.

Finally, further research is needed to expand understanding of how instructional materials support mathematical creativity across different educational settings. Future studies could examine creativity promotion in other mathematical content domains, such as geometry, statistics, probability, and calculus, as well as across different grade levels and national contexts. Comparative studies involving multiple curriculum systems may provide valuable insights into how curricular expectations are translated into textbook tasks. In addition, future research could investigate how teachers enact creativity-promoting tasks in classroom practice and how learners respond to such opportunities, thereby providing a more comprehensive understanding of the relationship between curriculum materials, instruction, and mathematical creativity.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been covered completely by the authors.

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