



Creative Math Preneurship Learning Model to Enhance Students' Creative Thinking and Educational Innovation Management

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ABSTRACT

Mathematics education in higher education requires learning that integrates mathematical creative thinking skills with the capacity to develop and manage innovation. An initial diagnostic study indicated that most students still experience difficulties in solving non-routine problems, particularly in the originality aspect. This study aims to develop the Math-Preneurship Creative learning model and to evaluate its validity, practicality, and changes in mathematical creative thinking ability after its implementation. This research employed the Research and Development (R&D) method with the Plomp development model, and the product quality criteria referred to validity, practicality, and effectiveness. Validation involved four experts, while the field trial was conducted with 38 fourth-semester students of the Mathematics Education Study Program at Universitas PGRI Semarang using a One-Group Pretest-Posttest Design. Data were collected through validation sheets, a mathematical creative thinking test ($\alpha = 0.86$; ICC = 0.88), an innovation management rubric based on the nine elements of the Business Model Canvas ($\alpha = 0.89$), and a practicality questionnaire. The results showed that the model and its supporting learning tools obtained an average validation score of 3.68 on a 4-point scale (very valid category) and a practicality level of 86.7% (very practical category). The average mathematical creative thinking ability increased significantly from 58.40 in the pretest to 84.30 in the posttest ($t = 14.82$; $p < 0.001$; Cohen's $d = 2.41$) with an N-gain of 0.62 (moderate-to-high category). The highest indicator achievement was obtained in fluency (87.5%), followed by flexibility (83.3%), elaboration (82.0%), and originality (77.6%). Students' performance on the BMC-based innovation management rubric reached 83.7%. These findings indicate that the Math-Preneurship Creative model meets the valid and practical criteria, and its implementation is accompanied by an increase in mathematical creative thinking ability and good achievement in BMC-based innovation management.



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Introduction

Mathematics education in higher education in the digital socio-economic era faces a fundamental paradigm shift. The demands of the workforce and the dynamics of 21st-century society no longer place passive material mastery as the primary achievement. Prospective mathematics teacher students are no longer sufficient to merely master procedural reasoning or technical symbolic manipulation that is mechanistic and isolated from practical reality (Bergqvist & Lithner, 2005; Schoenfeld, 1994). On the contrary, they are required to have Higher Order Thinking Skills (HOTS) integrated synergistically with learning management governance and an adaptive entrepreneurial spirit (Awwad & Louckes, 2020; Hendriana et al., 2018; Shuffa & Masrukan, 2026; Tudor, 2008).

In this context, mathematics education students specifically require innovation management capabilities, not merely general entrepreneurship abilities (Shatila, et. al., 2025). General entrepreneurship generally focuses on commercialization activities and ordinary transactional trade. In contrast, innovation management for prospective mathematics educators focuses on systematic capacity in managing abstract cognitive ideas, designing optimization modeling, analyzing efficiency, and managing risks to transform applied mathematics problems into value-added solutions, products, or learning media (value creation) (Tarigan, 2012). Based on the Semester Lesson Plan (RPS) of the Entrepreneurship course, students are expected to internalize the values of independence, innovation governance, and value creation in solving contextual problems based on applied mathematics (Sitorus & Masrayati, 2016). This integration becomes crucial so that graduates are not only theoretically robust but also possess managerial sharpness in transforming abstract concepts into economically and educationally valuable solutions.

Theoretically, the process of solving mathematical optimization problems (e.g., applied calculus or linear modeling) stimulates divergent cognitive activities in the form of fluency (the ability to generate many solution ideas) and flexibility (the ability to use diverse solving strategies) (Mann, 2006; Silver, 1997). The Innovation Management construct in this study is defined conceptually as students' managerial capacity to process and organize creative ideas resulting from mathematical problem solving. This study then operationalizes the innovation management construct through the 9-element Business Model Canvas (BMC) framework. When mathematical optimum solutions are transformed into BMC elements (such as Value Propositions, Customer Segments, and Cost Structure), students are forced to formulate original thinking (originality) in the form of non-food product/service ideas and detail operational business steps in a structured manner (elaboration) (Shanti, et.al, 2017). This integration answers the need for clarity of measurable managerial variables, so that mathematical thinking processes do not stop at calculation of numbers alone.

However, initial empirical facts in the Mathematics Education Study Program at Universitas PGRI Semarang show a fundamental cognitive gap between curriculum demands and the reality of student abilities. Based on a diagnostic study on 38 fourth-semester students using an initial test instrument for non-routine creative cognitive problem solving consisting of 4 HOTS essay items based on calculus/optimization, as many as 78.9% of students (30 out of 38 students) experienced significant obstacles and had not reached mastery criteria (score < 70 on a 0–100 scale). Students tended to be stuck on a single algorithmic solution and formula memorization schemes without being accompanied by deep conceptual understanding (Carson & Jamin, 2007; Purwosetiyono & Zuhri, 2023). The percentage achievement per indicator was calculated from the average proportion of scores obtained by students against the ideal

maximum score (0–4 scale per indicator), which showed concerning conditions: fluency was at 42.1%, flexibility 36.8%, elaboration 35.5%, and originality reached only 31.5%. This limitation occurs because contextual problems in lectures are often only functioned as formal initial examples without ever being optimized to explore business strategies and managerial feasibility comprehensively (Kadir & Lamasi, 2014; Supardi et al., 2026). As a result, students' creative thinking potential is constrained by rigid conventional learning patterns.

Scientific studies regarding the development of mathematical creativity (Leung & Silver, 1997; Mann, 2006; Siswono, 2018), integration of entrepreneurship education and math entrepreneurship (Awwad & Louckes, 2020), application of the BMC framework in education, as well as integrated mathematics and entrepreneurship learning models (Fiquyah et al., 2026; Hidayah et al., 2021) show the importance of alignment between analytical skills and real application orientation. Nevertheless, research gaps from previous studies (Agustina et al., 2020; Purwosetiyono et al., 2020a; Purwosetiyono & Zuhri, 2023) reveal the unavailability of a learning model that explicitly marries non-routine mathematical cognitive stages with business management governance based on the BMC framework systematically. The novelty of this study is realized through packaging the Math-Preneurship Creative Learning Model, which narratively guides students starting from contextual mathematical problem posing, divergent modeling, business value proposition framing, BMC-based operational management, to reflective evaluation and pitching. Based on this background and scientific urgency, this study aims to design and test the validity, practicality, and effectiveness of the Math-Preneurship Creative model in improving mathematical creative thinking ability and the effectiveness of students' innovation management. The results of this study are expected to provide theoretical and practical contributions to the renewal of mathematics learning models in higher education adaptive to digital era demands.

Method

Type of Research

This study used a Research and Development (R&D) approach using the Plomp model with a One-Group Pretest-Posttest Design. The quality of the developed product was evaluated based on three main criteria: validity, practicality, and effectiveness as proposed by Nieveen (Plomp & Nieveen, 2013). The developed products were in the form of the Math-Preneurship Creative learning model along with supporting instruments consisting of a Model Book, Teaching Book, integrative tasks, mathematical creative thinking assessment instrument, and Business Model Canvas (BMC)-based innovation management rubric. The development process was carried out iteratively through preliminary research, prototyping, and assessment phases. Evaluation and reflection were conducted at each phase to improve the product before being used in the next stage. Field testing used a One-Group Pretest-Posttest Design (Creswell & Guetterman, 2019), with measurements of mathematical creative thinking ability before and after model implementation. This design was used to obtain initial evidence regarding changes in student abilities after model implementation. Because the study did not use a comparison group, field test results were interpreted as initial evidence of model effectiveness and not used to draw strong causal conclusions.

Population and Sample

Research subjects consisted of expert validators and students involved in the field testing. There were four validators, consisting of two mathematics education experts and two educational management experts. Mathematics education experts were selected purposively based on expertise suitability with the characteristics of the developed model. Selection criteria included minimum academic qualification of a master's degree with academic rank of at least Senior Lecturer or doctoral degree in a relevant field, experience in higher education mathematics instruction, and publications or research experience in Higher Order Thinking Skills (HOTS), mathematical creative thinking, or learning model development. Educational management experts were selected based on competence in educational management, entrepreneurship, innovation development, or business model evaluation, with academic or professional experience of at least five years. Validators were tasked with assessing model conceptual suitability, instructional syntax integration, instrument indicator alignment, and model implementation feasibility. Field testing involved 38 fourth-semester students of the Mathematics Education Study Program at Universitas PGRI Semarang taking the Entrepreneurship course. Subject determination used total sampling, in which all students from two classes meeting these characteristics were involved as test subjects. Selection of the Entrepreneurship course context was based on suitability with model characteristics integrating mathematical problem solving, creative thinking, value creation, and business model development.

Operationalization of Variables

The research evaluated three aspects of product quality: validity, practicality, and initial model effectiveness. Validity refers to the conformity of the model and materials with theoretical foundations, learning objectives, student characteristics, learning syntax, and interconnection between mathematics and entrepreneurship activities. Practicality refers to ease of understanding, usage, and implementation by lecturers and students during learning. Mathematical creative thinking ability is defined as students' ability to produce and develop various strategies or solutions in solving non-routine mathematics problems. This ability was operationalized through four indicators: fluency, the ability to produce several ideas or solution possibilities; flexibility, the ability to use different strategies or representations; originality, the ability to produce relatively unique ideas or strategies; and elaboration, the ability to develop and explain solutions in detail and systematically. Innovation management in this study was operationally restricted as students' ability to organize ideas resulting from mathematical problem solving into a structured value creation design through nine BMC elements. This construct was not intended to represent all general innovation management aspects, but specifically described students' ability to develop and organize innovative ideas through Customer Segments, Value Propositions, Channels, Customer Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships, and Cost Structure.

Instrument

Four instruments were used to evaluate the instructional materials, assess student outcomes, and examine the practicality of the instructional model: an expert validation form, a mathematical creative thinking test, a Business Model Canvas (BMC)-based innovation

management rubric, and a practicality questionnaire. In addition, two creative math-preneurship tasks were used to integrate mathematical problem solving with business idea development. The instruments and tasks are described below.

Expert Validation Form

An expert validation form was used to evaluate the Model Book, Teaching Book, integrative tasks, mathematical creative thinking test, BMC-based innovation management rubric, and practicality questionnaire. The assessment addressed content relevance, alignment between instructional objectives and model syntax, accuracy of mathematical concepts, integration of entrepreneurship, clarity of language, feasibility of learning activities, and alignment with the intended constructs. Each criterion was rated on a four-point scale, ranging from 1 (not aligned) to 4 (highly aligned).

Mathematical Creative Thinking Test

The mathematical creative thinking test comprised four non-routine, constructed-response problems involving calculus and optimization. Students' responses were assessed using an analytic rubric covering four dimensions: fluency, flexibility, originality, and elaboration. Scores for each dimension ranged from 0 to 4.

Content validity was examined through expert judgments using the content validity ratio (CVR). The test demonstrated an internal consistency coefficient of Cronbach's $\alpha = .86$. Two independent raters scored students' responses, and inter-rater reliability, estimated using the intraclass correlation coefficient (ICC), was .88.

BMC-Based Innovation Management Rubric

The BMC-based innovation management rubric assessed students' ability to translate mathematical problem-solving results into a structured business innovation design. Students' work was evaluated across the nine dimensions of the BMC using a four-point rating scale. The rubric yielded an internal consistency coefficient of Cronbach's $\alpha = .89$.

Practicality Questionnaire

The practicality questionnaire was administered to the lecturer and students to examine their perceptions of the instructional model's implementation. It addressed five aspects: clarity of the instructional syntax, ease of participation in learning activities, readability of the instructional materials, adequacy of the allocated time, and perceived usefulness of the model. Responses were recorded on a five-point Likert scale.

Creative Math-Preneurship Integrative Tasks

Two integrative tasks were designed to connect mathematical creative thinking with business idea development. The tasks required students to interpret mathematical information, formulate and justify decisions, and relate their solutions to business planning. The first task focused on derivative-based analysis of a production-related profit function, whereas the second

involved the use of integral calculus to support production and cost planning. Table 1 summarizes the mathematical focus and entrepreneurial integration of each task.

Table 1. Description of Creative Math-Preneurship Tasks

Task	Task Characteristics
Task 1: Business Opportunity Analysis Based on Non-Routine Derivative Functions	Students are presented with a graph of a derivative function $P'(x)$ representing non-food production profits. Students must formulate an optimal strategy by analyzing: (1) positive profit intervals; (2) maximum turning points where $P'(x) = 0$; and (3) business implementation feasibility and operational management using the Business Model Canvas (BMC) instrument.
Task 2: Business Model Design Based on Integral Calculus	Students design production volume estimates, logistics management, and profit margin projections based on a given marginal cost function $MC(q) = 3q^2 - 12q + 15$, determining total cost $TC(q)$ via integral calculus and proving compliance with economic efficiency criteria.

Data Collection and Development Procedures

Data collection and model development were conducted in four operational phases guided by the Plomp development framework: preliminary research, prototyping, assessment, and reflection and finalization. The preliminary research phase identified the needs and contextual requirements for developing the Math-Preneurship Creative model through syllabus analysis, analysis of student characteristics, diagnostic testing, and a review of the literature on mathematical creative thinking, math-entrepreneurship instruction, innovation management, and the Business Model Canvas (BMC). The findings informed the design of the instructional model, learning materials, and assessment instruments.

During the prototyping phase, Prototype 1 was developed, comprising the Model Book, Teaching Book, integrative tasks, mathematical creative thinking test, BMC-based innovation management rubric, and practicality questionnaire. The model incorporated five instructional stages: Contextual Mathematical Problem Posing, Divergent Mathematical Modeling, Business Value Proposition Framing, BMC-Based Operational Management, and Reflective Evaluation and Pitching. Four expert validators evaluated Prototype 1, and their feedback informed revisions to the model and its supporting materials. This process resulted in Prototype 2, which was prepared for field testing.

The assessment phase involved a limited field test with 38 students. A mathematical creative thinking pretest was administered before instruction, after which Prototype 2 was implemented following the model's five instructional stages. At the end of the implementation, students completed the mathematical creative thinking posttest, BMC-based tasks, and practicality questionnaire. The lecturer also completed the practicality questionnaire. These data were used to examine students' mathematical creative thinking, their performance in developing BMC-based innovation designs, and participants' perceptions of the model's practicality. The reflection and finalization phase involved reviewing the implementation results, lecturer and student responses, pretest and posttest results, and students' performance on the BMC-based tasks. These findings informed the final revisions to the instructional model and its supporting materials, resulting in the finalized Math-Preneurship Creative model (See Figure 1).

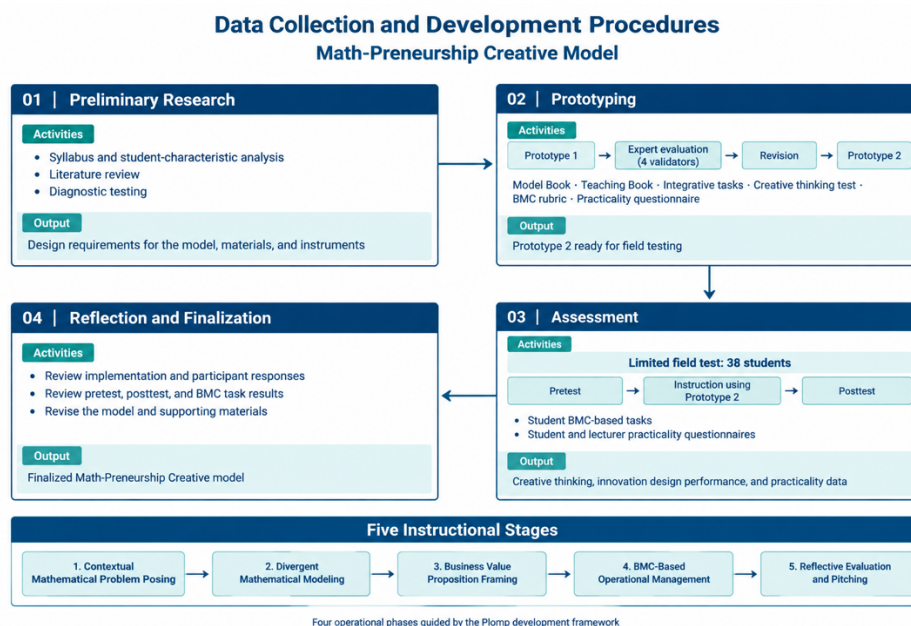


Figure 1. Data Collection and Development Procedures

Analysis

Data were analyzed using descriptive and inferential statistics to examine the validity and practicality of the Math-Preneurship Creative model, changes in students' mathematical creative thinking, and their performance in BMC-based innovation management. Expert validation ratings were analyzed descriptively by calculating the mean score for each assessment aspect and the overall mean score for each evaluated component. On the four-point rating scale, an overall mean score greater than 3.00 was used as the study's criterion for acceptable expert-rated validity. Aspect-level scores were examined to identify components requiring further revision.

Practicality questionnaire responses were analyzed by expressing the obtained scores as percentages of the maximum possible scores. The practicality percentage was calculated as the total obtained score divided by the maximum possible score, multiplied by 100. A percentage greater than 80% was used as the study's criterion for acceptable practicality. This analysis represented the proportion of the maximum attainable questionnaire score rather than the percentage of respondents providing positive responses.

Changes in mathematical creative thinking were examined by comparing students' pretest and posttest scores. A paired-samples *t*-test was conducted at a significance level of $\alpha = .05$, following assessment of the normality of the within-student difference scores. The relevant normality assumption concerned the posttest-minus-pretest differences rather than the pretest and posttest distributions separately. Normalized gain and a standardized effect size were calculated to complement the significance test. Group-level normalized gain was calculated as

$$g = \frac{\bar{X}_{\text{post}} - \bar{X}_{\text{pre}}}{X_{\text{max}} - \bar{X}_{\text{pre}}},$$

where $\bar{X}_{\text{pre}}$ and $\bar{X}_{\text{post}}$ denote the mean pretest and posttest scores, respectively, and X_{max} denotes the maximum possible test score. This specification represents the normalized gain of the group means, which is distinct from averaging students' individual normalized gains. For the paired design, the standardized mean change was expressed as Cohen's d_z , calculated by dividing the mean within-student difference by the standard deviation of the difference scores.

$$d_z = \frac{\bar{D}}{SD_D},$$

where $D = X_{\text{post}} - X_{\text{pre}}$. This definition explicitly identifies the standardizer used to quantify the magnitude of the observed change.

Students' BMC-based innovation management performance was analyzed descriptively across the nine BMC elements. Scores for each element and the overall rubric score were expressed as percentages of their corresponding maximum possible scores. These results were used to describe students' post-instruction performance in translating mathematical problem-solving results into structured business innovation designs. Because the BMC assessment was administered after instruction only, the analysis described attained performance rather than pretest–posttest improvement.

Research Findings

Expert Validation of the Model and Supporting Materials

Four experts, comprising two mathematics education experts and two educational management experts, evaluated the Math-Preneurship Creative model and its supporting materials. The evaluation covered mathematical content, the integration of entrepreneurship and innovation management, instructional design, and language and graphic quality. Table 2 summarizes the expert ratings on a four-point scale.

Table 2. Expert validation of the Math-Preneurship Creative model and supporting materials

Evaluation aspect	Mean score
Substance and accuracy of mathematical concepts	3.70
Integration of entrepreneurship and innovation management	3.68
Instructional design and model syntax	3.71
Language and graphic quality	3.62
Overall mean	3.68

Note. Ratings were recorded on a scale of 1–4. An overall mean greater than 3.00 constituted the study's criterion for acceptable expert-rated validity.

The overall mean score was 3.68, exceeding the specified validity criterion. Aspect-level means ranged from 3.62 to 3.71. Instructional design and model syntax received the highest rating, whereas language and graphic quality received the lowest, although all aspects exceeded 3.00. Expert feedback informed revisions to the time allocated to divergent mathematical modeling, allowing students more opportunity to explore cost optimization before developing their BMC designs.

Practicality of the Model

The practicality assessment involved the lecturer and 38 students. The reported questionnaire score was 86.7% of the maximum possible score, exceeding the study's practicality criterion of 80%. Participant feedback indicated that the instructional sequence was clear and that the contextual mathematical problems helped connect mathematical analysis with the development of operational business strategies. These findings supported the perceived practicality of the model in the limited field-test setting.

Changes in Mathematical Creative Thinking

Students' mathematical creative thinking scores increased from a pretest mean of 58.40 (SD = 8.12) to a posttest mean of 84.30 (SD = 6.45), corresponding to a mean increase of 25.90 points. The paired-samples analysis indicated a statistically significant difference between the two assessments, $t(37) = 14.82$, $p < .001$. The reported normalized gain was 0.62, and the reported Cohen's d was 2.41. Table 3 presents the descriptive and inferential results.

Table 3. Pretest–posttest results for mathematical creative thinking

Measure	Result
Number of students	38
Pretest mean (SD)	58.40 (8.12)
Posttest mean (SD)	84.30 (6.45)
Mean increase	25.90
Paired-samples t-test	$t(37) = 14.82$
p-value	$< .001$
Normalized gain	0.62
Reported Cohen's d	2.41

Note. The specific standardizer used to calculate Cohen's d should be identified in the Data Analysis section.

The post-instruction achievement percentages for the four creative thinking dimensions ranged from 77.6% to 87.5%. Fluency showed the highest achievement, followed by flexibility, elaboration, and originality. Table 4 presents the indicator-level results. Because corresponding pretest percentages were not reported for these dimensions, the findings describe their post-instruction achievement rather than dimension-specific gains.

Table 4. Post-instruction achievement across mathematical creative thinking dimensions

Dimension	Achievement (%)
Fluency	87.5
Flexibility	83.3
Originality	77.6
Elaboration	82.0

Note. Percentages represent the reported achievement scores for each dimension.

BMC-Based Innovation Management Performance

Students' overall performance on the BMC-based innovation management rubric reached 83.7% of the maximum possible score. This result summarized their performance across the nine BMC elements following instruction. As no corresponding baseline BMC assessment was reported, this finding represents post-instruction performance rather than an estimate of improvement in innovation management.

Student work from the two integrative tasks illustrated how mathematical analysis was connected with business model development. In Task 1, students analyzed a profit-derivative graph in the context of recycled wooden mathematical manipulatives. Their business designs addressed cost structure, the value proposition of durable and environmentally friendly manipulatives, and customer segments comprising secondary schools and tutoring centers. In Task 2, students used the marginal cost function $MC(q) = 3q^2 - 12q + 15$ to develop a total-cost expression through integration. Their accompanying BMC designs addressed key resources, channels involving digital mathematics kits, and partnerships with school networks. These examples illustrated the integration of calculus-based analysis with selected BMC components.

Discussion

Integrating Mathematical Exploration and Business-Oriented Decision Making

The findings provide preliminary support for the Math-Preneurship Creative model as an instructional approach that connects mathematical exploration with business-oriented decision making. The increase in mathematical creative thinking scores, together with students' post-instruction BMC performance, suggests that calculus-based tasks can provide a productive context for linking mathematical reasoning with the development of business ideas. However, these outcomes should be interpreted as evidence of promising performance within the implementation setting rather than proof that the model independently reduced cognitive barriers or produced entrepreneurial competence.

The model's potential contribution lies in the relationship between mathematical exploration and the subsequent organization of ideas. During contextual problem posing and divergent mathematical modeling, students are expected to formulate problems, consider alternative representations, and explore possible solutions (Awwad & Louckes, 2020; Carson & Jamin, 2007; Purwosetiyono & Zuhri, 2023). The value proposition and BMC stages then require them to select, justify, and organize these alternatives in relation to intended users, resources, costs, and delivery arrangements. Reflective evaluation and pitching further require students to communicate the rationale connecting their mathematical analyses with their proposed business designs. This sequence offers a plausible instructional explanation for how divergent exploration may be connected with more structured decision making. Nevertheless, the present study did not directly test whether these stages mediated the observed changes.

This interpretation is consistent with Silver's (1997) argument that mathematical creativity can be fostered through inquiry-oriented instruction rich in problem solving and problem posing, particularly through opportunities to develop fluency, flexibility, and novelty. Mann (2006) similarly emphasizes creative applications of mathematical knowledge rather than the replication of demonstrated procedures. The present model extends this instructional orientation by requiring students not only to generate mathematical alternatives but also to explain the practical implications of their selected solutions. Its proposed contribution is therefore not simply the addition of an entrepreneurship context to calculus tasks, but the deliberate connection between mathematical exploration, contextual justification, and business model articulation.

Interpreting the Changes in Mathematical Creative Thinking

The increase in mean scores from 58.40 to 84.30 indicates a substantial improvement in performance on the mathematical creative thinking assessment during the study period. The statistically significant paired comparison, normalized gain of 0.62, and reported Cohen's *d* of 2.41 provide complementary descriptions of this change. The significance test addresses the pretest–posttest difference, whereas the gain and effect-size estimates describe its magnitude under their respective calculation procedures. Nevertheless, the size of the observed change does not, by itself, establish that the instructional model was its sole cause.

A plausible explanation is that the integrative tasks provided repeated opportunities to interpret mathematical information and evaluate alternatives rather than merely reproduce a previously demonstrated algorithm (Panaoura & Panaoura, 2014). For example, analyzing a derivative graph in a production context required students to connect properties of a mathematical function with a proposed production decision (Sitorus & Masrayati, 2016). Similarly, integrating a marginal cost function required students to relate a symbolic expression to a cost model and its assumptions. When such tasks allow multiple defensible strategies or contextual interpretations, students have opportunities to move beyond procedural execution toward comparison and justification.

Importantly, contextualization and non-routine presentation should not automatically be equated with creative demand. Research comparing mathematical problem types found that creativity was most strongly associated with performance on open-ended, multiple-solution tasks; closed-ended non-routine problems did not necessarily show a stronger association than routine problems. Consequently, the educational value of the present tasks depends not only on their business setting but also on the extent to which students were genuinely allowed to formulate assumptions, consider alternative methods, and justify different feasible decisions. This distinction is important because a task can appear authentic while still directing all students toward a single predetermined procedure.

Uneven Achievement Across Creative Thinking Dimensions

The indicator-level findings suggest that students' post-instruction performance was uneven across the dimensions of mathematical creative thinking. Fluency received the highest percentage at 87.5%, followed by flexibility at 83.3%, elaboration at 82.0%, and originality at 77.6%. This pattern indicates that producing several responses and considering alternative approaches were more evident in the assessed work than generating responses judged to be original. However, because dimension-specific pretest scores were not reported, these differences describe the post-instruction profile rather than differential rates of development. One possible interpretation is that the instructional sequence made alternative generation more accessible than the production of genuinely distinctive ideas. Students could potentially vary solution methods or business applications while continuing to rely on familiar examples and established product categories (Shatila, et. al., 2025). Originality, by contrast, required responses that departed from commonly proposed approaches while remaining mathematically defensible and contextually meaningful. The lower originality score may therefore reflect a continuing tension between producing an unusual idea and maintaining confidence in its feasibility. This explanation remains a hypothesis because the reported quantitative results do not directly reveal students' reasoning or motivations.

The distinction also matters for interpreting the relationship between mathematical and entrepreneurial creativity. A novel product idea is not necessarily evidence of an original mathematical strategy, just as an unconventional mathematical solution does not automatically produce a novel business model. The evaluation of originality should therefore identify whether the intended object of assessment is the mathematical method, the contextual interpretation, the business proposal, or a specified combination of these. Without this distinction, originality scores may combine different forms of novelty and make the instructional implications difficult to identify.

Instructionally, the findings suggest a need to preserve opportunities for exploration before students finalize their BMC designs. Possible refinements include requiring students to propose contrasting solutions, explain how a new proposal differs from a familiar example, or revise an initial design after peer critique. These refinements are consistent with the emphasis on alternative approaches and novel solutions in creativity-oriented mathematics instruction, but their effectiveness within the present model remains to be investigated (Silver, 1997; Mann, 2006).

The Role and Limits of BMC-Based Performance

The overall BMC score of 83.7% indicates that students were able to produce assessed business model designs following instruction. The task examples further suggest that students connected calculus-based analyses with selected business considerations, including cost structure, value propositions, customer segments, resources, channels, and partnerships. The most defensible interpretation is that students demonstrated an ability to articulate business planning elements around mathematical task outcomes. Within the proposed model, the BMC may function as an organizing representation that makes the consequences of a mathematical decision more explicit. A production recommendation, for example, becomes more than a numerical answer when students must explain its implications for costs, resources, intended users, and delivery arrangements (Awwad & Louckes, 2020; Carson & Jamin, 2007; Purwosetiyono & Zuhri, 2023). The instructional significance lies in the coherence of these connections rather than in the completion of nine separate canvas elements. A mathematically correct calculation and a fully populated BMC do not necessarily constitute an integrated solution unless the business decisions can be traced to the mathematical analysis and its assumptions.

This distinction also limits the meaning of “innovation management effectiveness.” The BMC assessment captured the quality of student designs under classroom conditions; it did not directly assess market acceptance, sustained resource management, operational risk control, or actual business performance. Related research on BMC-based entrepreneurship instruction has likewise distinguished learning achievement from entrepreneurial intention: one quasi-experimental study reported improved learning achievement without establishing an improvement in entrepreneurial intention. Accordingly, the present findings should not be extended to claims about entrepreneurial readiness or real-world managerial effectiveness without additional evidence (Creswell & Guetterman, 2019).

The model also presents a potential instructional tension. A structured canvas can help students organize ideas, but introducing its categories too early may encourage them to prioritize completing the template over exploring alternatives. This was not directly measured in the study, yet it provides a useful direction for refinement. Maintaining an explicit distinction

between an initial exploration phase and a subsequent evaluation phase may help preserve creative possibilities while retaining the organizational benefits of the BMC.

Validity and Practicality as Conditions for Implementation

The expert validation mean of 3.68 and practicality score of 86.7% indicate that the model satisfied the study's specified acceptance criteria. These findings support different, complementary aspects of development. Expert ratings provide evidence concerning the judged appropriateness of the model and its supporting materials, whereas lecturer and student responses provide evidence concerning perceived usability during implementation. Neither form of evidence should be treated as interchangeable with evidence of learning effectiveness (Shanti, et.al, 2017). The revision to the time allocated for divergent mathematical modeling is particularly informative. It suggests that implementation quality depends not only on whether the instructional stages are logically arranged but also on whether students have sufficient time to explore alternatives before moving to business model formulation (Nuha et al., 2018). This observation is consistent with Mann's (2006) emphasis on the time and experience needed for mathematical creativity to develop. In practical terms, the transition from exploration to organization appears to be a design issue that deserves closer attention in subsequent iterations. The practicality percentage should nevertheless be interpreted within the limited field-test context. A favorable questionnaire score does not directly establish instructional fidelity, manageable lecturer workload, or comparable feasibility across institutions (Munandar, 2009; Purwosetiyono et al., 2020b). Furthermore, an overall percentage may conceal differences between lecturer and student perceptions or between specific aspects such as readability, time adequacy, and ease of participation. More detailed reporting would help identify whether the model was consistently practical or whether particular implementation demands remained.

Limitations and Directions for Further Research

Several limitations constrain the interpretation of the findings. First, the one-group pretest–posttest design does not separate the contribution of the model from alternative explanations, including repeated exposure to the assessment, other learning experiences, or changes occurring during the implementation period (Awwad & Louckes, 2020; Purwosetiyono et al., 2024). The large reported effect size describes within-group change and should not be interpreted as the model's advantage over another instructional approach. Second, the study involved a limited field test with 38 students. The findings therefore provide an initial basis for further development rather than broad evidence of effectiveness across courses, institutions, or student populations. The absence of delayed assessment also leaves unanswered whether the observed performance was sustained or transferred to unfamiliar mathematical and business contexts. Third, the BMC assessment was administered only after instruction, and corresponding baseline scores were not available. Similarly, the reported creative thinking dimension percentages did not include matched baseline values. These limitations prevent conclusions about improvement in specific BMC components or individual creative thinking dimensions. The reported diagnostic or mastery percentage should not be used as a baseline for originality unless it represents the same construct, scoring procedure, and measurement scale. Fourth, the proposed mechanisms were not directly examined. Future studies could investigate these processes through systematically analyzed solution records, successive BMC drafts,

classroom observations, or interviews. Such evidence would help distinguish an improvement in final products from a change in the reasoning processes that produced them.

Subsequent evaluations should compare the integrated model with an appropriate alternative condition, examine retention and transfer, and report outcomes separately for mathematical creativity and business model quality. A particularly informative comparison would distinguish the contribution of open-ended mathematical tasks from the additional contribution of BMC-based organization. This would clarify whether the observed outcomes arise primarily from task openness, business contextualization, structured reflection, or their interaction.

Implications for Mathematics Education

The principal implication is that entrepreneurship-oriented contexts can be used to extend the purposes of mathematical problem solving beyond obtaining a correct numerical result. In the proposed model, students are asked to explain what their mathematical conclusions imply for a contextual decision and how that decision connects with other elements of a business proposal. This approach offers a basis for designing learning experiences that combine analytical reasoning, alternative generation, and accountable decision making. At the same time, mathematical rigor should remain central. Business interpretations need to be supported by appropriate assumptions, valid calculus reasoning, and a clear distinction between what the mathematical model establishes and what requires additional economic or contextual information. The model is therefore best understood as a promising framework for coordinating mathematical exploration with structured application, rather than as a demonstrated solution to cognitive rigidity or a substitute for comprehensive entrepreneurship education. Its contribution will be more firmly established through comparative evidence and closer examination of how students connect mathematical arguments with their business decisions.

Conclusion

This study developed and evaluated the Math-Preneurship Creative learning model, which integrates non-routine mathematical problem solving with structured business model development using the Business Model Canvas (BMC). The model met the study's validity and practicality criteria, with an overall expert rating of 3.68 out of 4 and a practicality score of 86.7%. Mathematical creative thinking scores increased from a pretest mean of 58.40 to a posttest mean of 84.30, with a normalized gain of 0.62. Students' final BMC-based innovation management performance reached 83.7% of the maximum possible score. These findings provide preliminary support for the model's feasibility and its potential to support mathematical creative thinking while connecting mathematical analysis with business-oriented decision making. The model's principal contribution is an instructional sequence that connects divergent mathematical exploration with the formulation, organization, and justification of business ideas. However, the single-group design and the participation of 38 students from one institution limit causal inference and generalizability. Furthermore, the absence of an equivalent baseline BMC assessment means that the final BMC score represents attained performance rather than demonstrated improvement. The model should therefore be regarded as a promising instructional approach requiring further evaluation, rather than an established alternative to existing instruction. Future research should employ controlled quasi-experimental designs

across multiple institutions, comparable pretest–posttest assessments of both outcomes, and delayed follow-up measures to examine the durability and transfer of learning.

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Declarations

- Conflict of Interest** : The authors declare that there are no conflicts of interest.
- Auhor Contributions** : F.X.D.P.: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, resources, supervision, visualization, and writing—original draft.
M.S.Z.: Conceptualization, formal analysis, investigation, methodology, resources, software, validation, and writing—review and editing.
M.N.H.: Data curation, investigation, project administration, validation, visualization, and writing—review and editing.
All authors have read and approved the final version of the manuscript.
- Data Availability Statement** : The data supporting the findings of this study are available from the corresponding author, F.X.D.P., upon reasonable request
- AI Statement** : The authors state that generative AI tools were used solely to improve the clarity, grammar, and readability of the English language in the manuscript.

References

- Agustina, M., Purwosetiyono, F. D., Buchori, A., & Osman, S. (2026). Design thinking approach in the development of e-worksheets and AI videos to enhance problem-solving skills of senior high school students. *Mosharafa: Jurnal Pendidikan Matematika*, 15(1), 21–36. <https://doi.org/10.31980/mosharafa.v15i1.2156>
- Awwad, A., & Louckes, M. (2020). Integrating entrepreneurship and management in education: Adaptability and economic challenges. *Journal of Business Education*, 95(6), 332–340. <https://doi.org/10.1080/08832323.2020.1743211>
- Bergqvist, E., & Lithner, J. (2005). Mathematical reasoning in service course exams. *The Journal of Mathematical Behavior*, 24(2), 153–169. <https://doi.org/10.1016/j.jmathb.2005.03.003>
- Carson, J., & Jamin, L. (2007). Procedural steps in mathematical problem solving. *Journal of Mathematical Thought*, 14(2), 89–104. https://link.springer.com/chapter/10.1007/978-3-319-40730-2_1
- Creswell, J. W., & Guetterman, E. D. (2019). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (6th ed.). Pearson Education.

- https://www.researchgate.net/publication/324451568_Educational_Research_Planning_Conducting_and_Evaluating_Quantitative_and_Qualitative_Research_6th_Edition
- Fiqriyah, N., Aras, A., Buhaerah., & Ahsan, M. (2026). Exploration of ethnomathematics in the Mandar traditional house as a source of deep learning-based instruction in schools. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, 6(3), 921–937. <https://doi.org/10.51574/kognitif.v6i3.2109>
- Hendriana, H., Rohaeti, E. E., & Sumarmo, U. (2018). Hard skills dan soft skills matematik siswa. Refika Aditama.
- Hidayah, I., Wardono, W., & Buana, Y. (2021). Literasi numerasi dan manajemen inovasi dalam pemecahan masalah kompleks. *Jurnal Inovasi Pendidikan Matematika*, 7(2), 102–115. <https://doi.org/10.22236/KALAMATIKA.vol4no1.2019pp69-88>
- Kadir, K., & Lamasi, L. (2014). Optimalisasi konteks masalah dalam membangun konsep kreatif. *Jurnal Daya Matematis*, 2(1), 45–56. <https://doi.org/10.26858/jdm.v2i1.1245>
- Leung, S. O., & Silver, E. A. (1997). The role of problem posing in mathematical creativity. *Educational Studies in Mathematics*, 34(3), 243–267. <https://doi.org/10.1023/A:1002973606901>
- Mann, E. L. (2006). Creativity: The essence of mathematics. *Gifted Child Today*, 29(3), 45–49. <https://doi.org/10.4219/gct-2006-217>
- Munandar, U. (2009). Pengembangan kreativitas anak berbakat. Rineka Cipta.
- Nuha, M. A., Purwanto, P., & Subanji, S. (2018). Efikasi diri dan manajemen pembelajaran digital dalam berpikir kreatif. *Jurnal Riset Pendidikan Matematika*, 5(2), 210–222. <https://doi.org/10.21831/jrpm.v5i2.21345>
- Panaoura, G., & Panaoura, A. (2014). Dominansi kefasihan dan fleksibilitas dalam praktik pengajaran. *European Journal of Science and Mathematics Education*, 2(3), 145–158. <https://doi.org/10.30935/ejsme/9406>
- Plomp, T., & Nieveen, N. (2013). Educational design research: An introduction. Netherlands Institute for Curriculum Development (SLO).
- Polya, G. (1945). How to solve it: A new aspect of mathematical method. Princeton University Press. <https://doi.org/10.1515/9781400828678>
- Purwosetiyono, F. D., Rubowo, M. R., & Nursyahidah, F. (2020a). Pengembangan task book matematika dengan model problem based learning untuk meningkatkan berpikir kreatif siswa kelas VII. *Prosiding Seminar Nasional Matematika dan Pendidikan Matematika*, 5, 408–415. <https://103.98.176.39/index.php/senatik/article/view/1010>
- Purwosetiyono, F. D., & Zuhri, M. S. (2023). Hambatan kreativitas dan algoritma dalam pemecahan masalah matematika. *Jurnal Penelitian Pendidikan Matematika*, 9(2), 115–128. <https://doi.org/10.21831/jpms.v8i2.19662>
- Purwosetiyono, F. X. D., Sa'dijah, C., Hidayanto, E., & Chandra, T. D. (2020b). The originality idea of prospective teacher's in mathematics problem solving. *Test Engineering and Management*, 83, 23648–23663. <http://www.testmagzine.biz/index.php/testmagzine/article/view/12070>
- Purwosetiyono, F. X. D., Sadijah, C., Hidayanto, E., Candra, T. D., As'ari, A., & Irawan, E. B. (2018). Prospective teachers conception of mathematical creative thinking. *International Journal of Insight for Mathematics Teaching*, 1(2), 106–114. <https://journal2.um.ac.id/index.php/ijoint/article/view/3416>
- Purwosetiyono, F., Shodiqin, A., & Wardani, T. (2024). Development of creative alternative assessments for mathematics learning using a design thinking approach. KONTINU:

- Jurnal Penelitian Didaktik Matematika*, 8(2), 170–182.
<https://doi.org/10.30659/kontinu.8.2.170>
- Schoenfeld, A. H. (1994). Mathematical thinking and problem solving. Routledge.
<https://doi.org/10.4324/9781315044613>
- Shanti, W. N., Sundawati, M., & Sastrawati, N. (2017). Proses berpikir divergen yang sistematis dalam pendidikan modern. *Jurnal Edukasi Matematika*, 8(1), 12–25.
<https://jurnal.untirta.ac.id/index.php/JPPM/article/view/13409>
- Shatila, A. G., Buchori, A., & Purwosetiyono, F. D. (2025). Analisis kebutuhan desain pembelajaran inovatif berbasis media AI untuk meningkatkan kemampuan pemecahan masalah. *Teorema: Teori dan Riset Matematika*, 10(1), 75–82.
<https://doi.org/10.25157/teorema.v10i1.13456>
- Shuffa, A. F., & Masrukan. (2026). Mathematical critical thinking skills based on self-efficacy in teams games tournament (TGT) cooperative learning assisted by Baamboozle. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, 6(3), 1053–1072.
<https://doi.org/10.51574/kognitif.v6i3.2188>
- Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving. *ZDM – Mathematics Education*, 29(3), 75–80. <https://doi.org/10.1007/s11858-997-0003-x>
- Siswono, T. Y. E. (2018). Pembelajaran matematika berbasis pemecahan masalah. Deepublish.
- Sitorus, J., & Masrayati, M. (2016). Lingkungan belajar kolaboratif dan kemampuan berpikir kreatif. *Jurnal Kependidikan*, 46(1), 33–44. <https://doi.org/10.21831/jk.v46i1.9572>
- Supardi, Khairunnisa, A., Maulana., & Isrok'atun. (2026). Effectiveness of PMRI assisted by VERULI on elementary school students' mathematical problem-solving skills. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, 6(3), 1073–1094.
<https://doi.org/10.51574/kognitif.v6i3.2195>
- Tarigan, D. (2012). Titik balik pendidikan matematika melalui langkah sistematis Polya. *Jurnal Pendidikan Matematika Indonesia*, 1(1), 10–19.
<https://doi.org/10.22236/KALAMATIKA.vol1no1.2016pp59-70>
- Tudor, R. (2008). Contextual problems as a foundation for creative instruments. *Journal of Mathematics Teaching*, 33(2), 88–95.
https://www.researchgate.net/publication/221407831_Contextual_Factors_which_Influence_Creativity_in_Requirements_Engineering

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