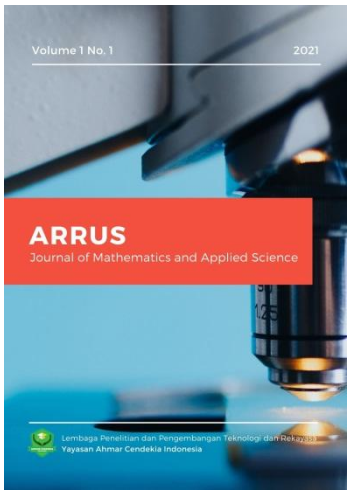
https://doi.org/10.35877/mathscience5520

OPEN ACCESS

ISSN : 2776-7922 (Print) / 2807-3037 (Online)



REVIEW ARTICLE

Mathematical Modeling as a Cognitive Tool for Evaluating Entrepreneurial Opportunities: A Systematic Literature Review

Jahring[1*], Marniati[2], Tahir[3], Hamda[4]

[1,2,3]Mathematics Education Department, Faculty of Teacher Training and Education, Universitas Sembilanbelas November Kolaka, Kolaka, Indonesia. Email: jahring.usn@gmail.com, marniati1387@gmail.com, tahir.anwar.ta89@gmail.com

[4]Mathematics Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar, Makassar, Indonesia. Email: hamdamath@unm.ac.id

Abstract: This study maps how the literature treats mathematical modeling and quantitative reasoning in entrepreneurship education and opportunity evaluation, identifies the cognitive and contextual processes involved in recognizing and evaluating opportunities, and proposes a conceptual framework that links the two bodies of work. The study applies a systematic literature review, reports record selection following PRISMA 2020, and analyzes the extracted data thematically. Searches covered Scopus, Web of Science, ScienceDirect, IEEE Xplore, and Taylor & Francis Online, plus four Indonesian national journals, and returned 309 records. After deduplication, screening, and full-text assessment, 12 journal articles remained for synthesis. The results show three themes: mathematics and modeling within entrepreneurship education, cognitive and contextual processes in opportunity evaluation, and technology-enabled and emerging-economy settings. Eight of the 12 articles appeared in 2024–2026, and none of them tests whether modeling improves the quality of opportunity evaluation. The synthesis yields a six-stage conceptual framework: opportunity contextualization, variables and assumptions, mathematization, scenario analysis, interpretation and validation, and decision considerations. The findings of this study suggest that modeling can be read as a reflective cognitive tool that makes assumptions and reasoning open to inspection, while the evidence base remains conceptual and educational rather than outcome-based.

Keywords: Mathematical modeling, Opportunity evaluation, Entrepreneurship education, Entrepreneurial cognition, Systematic literature review

*Corresponding author: Jahring, Mathematics Education Department, Faculty of Teacher Training and Education, Universitas Sembilanbelas November Kolaka, Kolaka, Indonesia.

E-mail: jahring.usn@gmail.com

1. Introduction

Evaluating an entrepreneurial opportunity asks a person to judge whether an idea meets a real need, whether the available resources can carry it out, and whether it survives changes in cost, price, or demand. In classrooms the same task becomes a requirement. Students must produce business ideas and also explain why they pursue, adjust, or drop them. Evidence from outside education points the same way. A fuzzy-set qualitative comparative

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

analysis published in 2026 found that evaluations of technological opportunities arise from combinations of technological awareness, risk tolerance, and social influence, and that no single condition was a prerequisite for a high evaluation (Andrade-Valbuena & Dos Santos, 2026).

Mathematical modeling offers one way to make such reasoning explicit. Modeling translates a real situation into a mathematical representation, works within that representation, and interprets the result in the original context. In this sense it helps a decision maker name variables, state assumptions, compare scenarios, and examine what follows from a choice (Cevikbas et al., 2022; Geiger et al., 2022). Opportunity evaluation, for its part, concerns the attractiveness and development potential of a venture under incomplete information, risk, experience, and social influence (Camelo-Ordaz et al., 2020; Sassetti et al., 2022). A model gives that judgment an analytical structure. It does not replace the judgment.

Existing work approaches the topic from separate directions. Sun and Yang (2025) combine modeling instruction with innovation and entrepreneurship education and use cluster analysis to group learning patterns and adapt teaching strategies. Samsul et al. (2025) link problem- and project-based learning to entrepreneurial character and mathematical reasoning, and Yani and Suryawan (2025) review how entrepreneurship and mathematics learning relate. Research on opportunities has taken a different route. It examines cognitive and contextual configurations, the way opportunities are perceived and interpreted, and the definition of the concept itself (Andrade-Valbuena & Dos Santos, 2026; Chen et al., 2024; Schlichte & Junge, 2025). Each strand covers a relevant element, yet each has its own objectives and vocabulary.

Other studies add context without joining the strands. Entrepreneurship-oriented mathematics materials have been examined for their effect on problem solving (Lidiana & Sukestiyarno, 2023), and problem-based learning has been proposed to strengthen learner agency in entrepreneurship courses (Chandra et al., 2024). A microlearning platform for edutechpreneurship reported higher post-test than pre-test scores among 100 university students (Nurhikmah et al., 2025). Other work operationalizes the feasibility of e-entrepreneurial ideas (Lin et al., 2024), analyzes startup decisions that mix trial and error with hypothesis testing (Gonzalez-Tamayo et al., 2025), and models risk and uncertainty trade-offs in opportunity decisions (Bird et al., 2025). Analytical versus intuitive cognitive style has been tied to decision logic under environmental uncertainty (Wei et al., 2024), and a survey of 219 civil servants treats unstable environments as a condition that shapes organizational agility (Gunawan et al., 2025). These studies supply context. They do not show that mathematical modeling improves entrepreneurial outcomes.

The gap, then, is not a shortage of studies on mathematics or on entrepreneurship. It is the missing link between them. Educational research centers on learning and reasoning, while entrepreneurship research addresses opportunity recognition, risk, and cognition, usually without describing the role of mathematical representations (Hidayat et al., 2025; Samsul et al., 2025; Sassetti et al., 2022; Schlichte & Junge, 2025). Within the searches reported here, the authors did not locate a synthesis that connects modeling, evidence-based reasoning, and the assessment of business opportunities.

This review therefore offers a bridge, not a verdict. It brings the literature on mathematical modeling and entrepreneurship education together with research on cognition and opportunity evaluation, and it proposes a conceptual framework that links problem context, variables and assumptions, mathematization, scenario analysis, interpretation, and decision considerations. The aim is to keep the contribution of mathematics from shrinking to computational skill and to treat it as a means of structuring reasoning and testing the consequences of decisions. The review follows PRISMA 2020 and synthesizes 12 journal articles thematically. Three research questions guide it:

> RQ1: How does the literature explain the role of mathematical modeling or quantitative reasoning in entrepreneurship education and opportunity evaluation?

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

RQ2: Which cognitive and contextual processes does the literature identify as key elements in recognizing and evaluating entrepreneurial opportunities?

RQ3: How can findings from these two bodies of literature be synthesized into a conceptual framework for mathematical modeling as a cognitive tool for entrepreneurial opportunity evaluation?

The objective is to map the relevant evidence, identify links and gaps between themes, and propose a framework that later empirical work and instructional design can build on.

2. Literature Review

2.1. Mathematical modeling as a reasoning tool

Research on modeling competence describes a cycle in which a person interprets a situation, builds a mathematical representation, works within it, interprets the result, and checks it against the situation. A systematic review of this discussion organizes the work into conceptualizing, measuring, and developing modeling competencies (Cevikbas et al., 2022). A task design framework adds that modeling tasks need authentic problems and deliberate support for reflection (Geiger et al., 2022). A review of teaching practice points to representation and reflection on the model itself as recurring features of good practice (Hidayat et al., 2025). An eye-tracking review adds that open-ended geometry and visual modeling tasks invite divergent exploration, although only five empirical studies met its criteria (Farman et al., 2025). Seen this way, modeling is more than the use of formulas. It is a disciplined way of making assumptions visible and of asking what follows from them.

In entrepreneurship education, the same cycle can be attached to business problems: a student estimates costs, sets prices, projects demand, and then questions each estimate. The corpus reviewed below tests only parts of this idea, mostly at the level of learning and reasoning (Samsul et al., 2025; Sun & Yang, 2025).

2.2. Cognition and context in opportunity evaluation

The entrepreneurship literature treats opportunity recognition and evaluation as cognitive and social processes. A socio-cognitive approach explains recognition through the interaction of individual cognition and institutional context (Camelo-Ordaz et al., 2020). Reviews of entrepreneurial alertness connect the construct to opportunity recognition and to several entrepreneurial outcomes (Chavoushi et al., 2021; Lanivich et al., 2022). A long-running debate asks whether opportunities are discovered or created, and recent conceptual work argues that they are possibilities realized through action and therefore never fully determined in advance (Chen et al., 2024; Schlichte & Junge, 2025). Reasoning by analogy and abduction has also been proposed as a mechanism through which entrepreneurs frame unfamiliar situations (Sergeeva et al., 2021).

These accounts share a point that matters for modeling. Evaluation depends on information, experience, and context, and much of that material is not numerical. A model built on weak data or on unexamined assumptions can look precise and still mislead. The review keeps this tension in view when it asks what modeling can and cannot contribute.

3. Research Method and Materials

This study uses a systematic literature review. Record selection follows PRISMA 2020 and covers identification, screening, eligibility assessment, and inclusion (Page et al., 2021). The substantive synthesis uses thematic analysis organized around the three research questions. The review is a conceptual synthesis. It maps what published studies report and does not pool effect sizes.

3.1. Search strategy

Searches covered five bibliographic databases: Scopus, Web of Science, ScienceDirect, IEEE Xplore, and Taylor & Francis Online. Google Scholar served as a supplementary

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

source for articles that the main databases might have missed, and four SINTA-indexed Indonesian national journals contributed additional records. The sources span mathematics education, quantitative modeling, entrepreneurship, and decision-making. Because each platform has its own scope and syntax, the strings were adapted to each database while the core concepts stayed constant. The searches were run on.

Keywords formed three conceptual groups. The first string targets modeling and entrepreneurship directly: ("mathematical modelling" OR "mathematical modeling" OR "mathematical model") AND (entrepreneurship OR entrepreneur OR "entrepreneurial opportunity"). The second covers quantitative reasoning in opportunity recognition: ("quantitative reasoning" OR "mathematical reasoning" OR "mathematical literacy" OR "quantitative analysis") AND ("opportunity evaluation" OR "opportunity assessment" OR "opportunity recognition") AND (entrepreneurship OR entrepreneur). The third addresses entrepreneurial learning, decisions, and problem solving: ("entrepreneurship education" OR "entrepreneurial learning") AND ("decision making" OR reasoning OR "problem solving") AND (mathematical OR quantitative OR modelling OR modeling).

OR joined equivalent terms and spelling variants, AND joined concept groups, and quotation marks searched exact phrases. Searches were limited to 2020–2026 and to articles in English or Indonesian. In total, 309 records were identified: 305 from the five databases and four from national journals.

3.2. Eligibility criteria

Selection followed predefined inclusion and exclusion criteria on publication period, status, type, source verification, language, full-text access, thematic relevance, information sufficiency, and record uniqueness (Table 1). Publication status was checked on publisher pages and DOI records. An article had to exist as a formally published journal article by the search date, and online-first articles with a DOI were accepted, but preprints and manuscripts without a publisher record were not.

Table 1: Inclusion and Exclusion Criteria for Study Selection

Criterion	Inclusion criteria	Exclusion criteria
Publication period	2020–2026; publication date confirmed on or before the search date.	Outside the stated period or after the search date.
Publication status	*3.3. Peer-reviewed journal articles with a publisher page and DOI, including online-first articles.*	Preprints, accepted manuscripts without a publisher record, or items with unverifiable status.
Publication type	Empirical studies, relevant systematic reviews, and theoretical or conceptual journal articles.	Books, book chapters, proceedings, theses, dissertations, and non-peer-reviewed items.
Source verification	Identifiable journal and publisher page, DOI or persistent URL, and verifiable metadata.	Records with unverifiable publication status or bibliographic identity.
Language	English or Indonesian.	Other languages.
Full-text availability	Complete text accessible for review of methods and evidence.	Abstract only or inaccessible full text.
Thematic relevance	Substantive contribution to at least one research question on modeling or quantitative reasoning, entrepreneurship education, entrepreneurial cognition, or opportunity evaluation.	Incidental mention of the topic without a substantive link to the review questions.
Information sufficiency	Enough detail on aims, methods, arguments, or findings for thematic extraction.	Insufficient extractable information.
Record uniqueness	Distinct publications retained after deduplication.	Duplicate records of the same publication.

Note: Criteria were defined before screening and applied at both the title-abstract and full-text stages.

Table 1 lists nine criteria. At the screening stage the period and thematic relevance criteria excluded most records (Fig. 1). The status and source verification criteria worked mainly at

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

the full-text stage, where they separated formally published articles from items whose bibliographic identity could not be confirmed.

3.4. Screening and selection

Records from all sources were exported to a common bibliographic format and merged into one working set. Duplicates were identified through title, author, year, DOI, and other bibliographic fields, and near-matches with different metadata were reviewed manually. Selection then moved through title and abstract screening, full-text examination, and a final decision against all inclusion criteria, with reasons for exclusion recorded at the full-text stage. Figure 1 reports the flow.

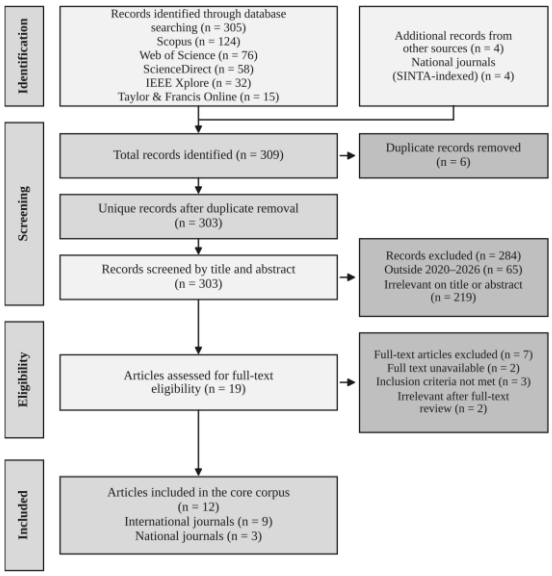


Figure 1: PRISMA 2020 Flow Diagram of Record Selection

Figure 1 shows that 6 duplicates were removed from the 309 records, leaving 303 for screening. Title and abstract screening excluded 284 records: 65 whose verified publication date fell outside 2020–2026 and 219 that were irrelevant to the review questions. Of the 19 articles assessed in full, seven were excluded (two without accessible full text, three that did not meet the inclusion criteria, and two that proved irrelevant on reading). Twelve articles entered the synthesis, nine from international journals and three from Indonesian national journals. The inclusion rate was 4.0% of the screened records.

3.5. Data extraction and analysis

Data from each included article were recorded on a standardized form: authors, year, title, journal, DOI, country or study context where reported, objectives, design and methods, participants or units of analysis, the modeling or reasoning concepts discussed, the cognitive aspects or evaluation processes examined, key findings, limitations reported by the authors, and the article's contribution to each research question.

The analysis was thematic. First, relevant findings and concepts were read and given initial codes, such as mathematical representation, assumption setting, quantitative reasoning, opportunity recognition, risk evaluation, scenario analysis, decision making, and entrepreneurial learning. Second, codes with related meanings were grouped into themes. Third, themes were compared across articles to find recurring patterns, differences in approach, tensions, and thinly covered areas. Fourth, the results were mapped to the research questions and used to formulate the conceptual framework.

No formal quality or risk-of-bias tool was applied. The review therefore describes what the included studies report and does not grade the strength of their evidence. Because the

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

corpus mixes empirical, conceptual, and review articles, the analysis treats them as complementary sources of ideas and does not combine their results quantitatively.

4. Results and Discussion

4.1. Study characteristics

The corpus holds 12 journal articles. By publication year, one appeared in 2020, one in 2021, two in 2022, none in 2023, one in 2024, four in 2025, and three in 2026 (Fig. 2a). Eight articles (66.7%) date from 2024–2026 and four (33.3%) from 2020–2022. These figures describe the selected corpus only. They were not computed from all 309 retrieved records and cannot be read as a trend in the field.

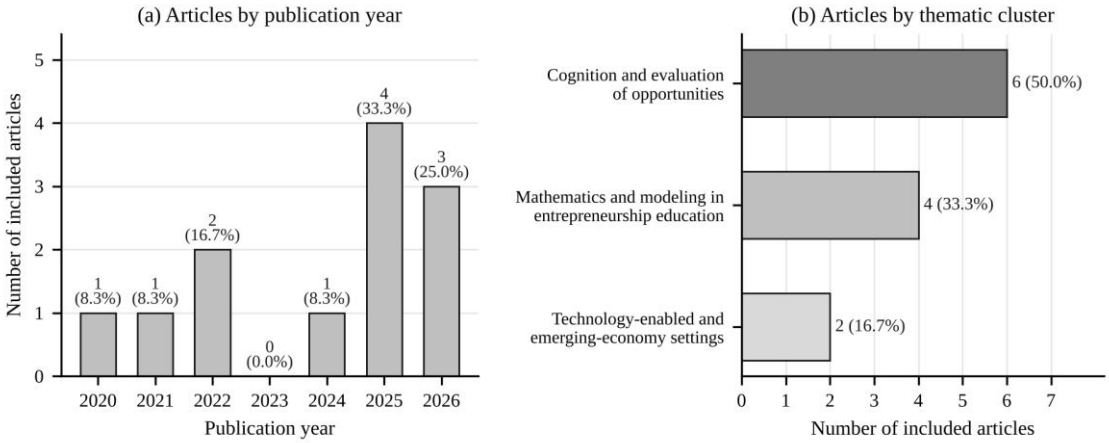


Figure 2: Included Articles by Publication Year and Thematic Cluster

Panel (a) of Figure 2 shows an empty year in 2023 and a peak in 2025. With 12 articles, one study moves a bar by 8.3 percentage points, so the panel shows a distribution and not a trend. Panel (b) shows that half of the corpus (six articles) sits in the cognition cluster and one third (four articles) in the cluster that deals with mathematics and modeling in education. The technology cluster is the smallest, with two articles.

The clusters are as follows. Cluster 1 links mathematics or modeling to entrepreneurship education. It includes the integration of a modeling course with innovation and entrepreneurship education (Sun & Yang, 2025), problem- and project-based learning for entrepreneurial character and reasoning (Samsul et al., 2025), the relationship between entrepreneurship and mathematics learning (Yani & Suryawan, 2025), and mathematics as a foundation for business ideas (Darmayanthi et al., 2022). Cluster 2 addresses cognition and the evaluation of opportunities: socio-cognitive recognition (Camelo-Ordaz et al., 2020), analogical abduction (Sergeeva et al., 2021), alertness and cognitive style (Sassetti et al., 2022), the discovery-creation debate (Chen et al., 2024), a conceptual map of the field (Schlichte & Junge, 2025), and cognitive-contextual configurations (Andrade-Valbuena & Dos Santos, 2026). Cluster 3 widens the setting to emerging economies and artificial intelligence (Azam et al., 2026; D'Angelo et al., 2026). Table 2 summarizes each article.

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

Table 2: Characteristics of the 12 Included Studies

No	Author (year)	Design (review coding)	Cluster	Key finding relevant to this review
1	Sun & Yang (2025)	Instructional strategy, cluster analysis	C1	Integrating a modeling course with innovation and entrepreneurship education; grouping of learning patterns tailors instruction.
2	Samsul et al. (2025)	Instructional model development	C1	Problem-project model rated practical and effective; entrepreneurial character improved and mathematical reasoning reached a high category.
3	Yani & Suryawan (2025)	Systematic literature review	C1	Entrepreneurial values enter mathematics teaching through social arithmetic, geometry, media, and challenge-based learning; obstacles are time, teacher training, and readiness.
4	Darmayanthi et al. (2022)	Conceptual, literature-based	C1	Mathematics treated as a foundation for business ideas, innovation, and products with commercial value.
5	Camelo-Ordaz et al. (2020)	Empirical, moderation model	C2	Self-efficacy and outcome expectations raise opportunity recognition; institutional dimensions strengthen only the self-efficacy path.
6	Sergeeva et al. (2021)	Conceptual, pragmatist account	C2	Analogical abduction frames new situations; consequences of action revise conjectures and assumptions.
7	Sassetti et al. (2022)	Empirical, mediation model	C2	Alertness is linked to decision effectiveness; a rational cognitive style mediates, an intuitive style does not.
8	Chen et al. (2024)	Conceptual	C2	Opportunities are possibilities realized through action and cannot be fully determined in advance.
9	Schlichte & Junge (2025)	Literature review	C2	Maps perspectives and determinants in opportunity research and identifies gaps and directions.
10	Andrade-Valbuena & Dos Santos (2026)	Empirical, fsQCA	C2	Evaluation arises from combinations of technological awareness, risk tolerance, social influence, effort expectancy, and perceived innovativeness; no single necessary condition.
11	Azam et al. (2026)	Empirical, mediation and moderation	C3	Recognition mediates between cognitive and contextual factors and exploitation; intelligence and social capital moderate.
12	D'Angelo et al. (2026)	Theoretical framework	C3	Artificial intelligence takes part in entrepreneurial learning and venture creation through cognitive activities and task execution.

Note: C1 = mathematics and modeling in entrepreneurship education; C2 = cognition and evaluation of opportunities; C3 = technology-enabled and emerging-economy settings. Design labels are the review's own coding.

Table 2 shows an uneven corpus. Only the four Cluster 1 articles take mathematics or modeling as their subject, and their designs are mostly instructional or conceptual. The Cluster 2 and Cluster 3 articles do not examine mathematical representations in their key findings. The corpus therefore offers direct evidence on how mathematics enters entrepreneurship teaching and indirect evidence on how opportunities are evaluated. The years in Table 2 are final journal citation years, and the design labels are this review's own coding. The convergence of the two strands motivates the framework below. It is not a pooled estimate of effectiveness and does not validate the framework.

4.2. Modeling and quantitative reasoning in entrepreneurship education (RQ1)

The most direct link between modeling and entrepreneurship appears in education. Sun and Yang (2025) integrate a modeling course with innovation and entrepreneurship education and use business problems as the setting in which analytical and innovative skills are practiced. In mathematics education, Samsul et al. (2025) developed a problem-project model that their evaluation rated practical and effective, with improved entrepreneurial character and mathematical reasoning at a high level. Together the two studies suggest that an entrepreneurial context gives mathematics a meaningful setting, and that mathematics helps learners organize information and state the reasons for their choices.

The evidence has limits. A modeling-based course shows how students learn. It does not show whether models improve the accuracy of an opportunity assessment or the quality of

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

an investment decision. The corpus mixes two kinds of outcome that are easy to confuse: educational outcomes, such as reasoning skill and entrepreneurial character, and decision outcomes, such as feasibility judgments, risk weighing, and opportunity selection. This review treats modeling as a candidate mechanism linking the two. The link still needs direct testing.

Conceptually, modeling can serve opportunity evaluation through four functions. It reduces a business situation to variables that can be analyzed, brings hidden assumptions to the surface, compares scenarios for costs, prices, and demand, and tests how sensitive a decision is to changed conditions. These functions go beyond applying formulas, because they make reasoning open to review, criticism, and revision. The relationship between entrepreneurship and mathematics learning gives the broader background (Yani & Suryawan, 2025), and work on modeling competence points to authentic tasks and reflection on the model (Cevikbas et al., 2022; Hidayat et al., 2025).

Two articles place modeling inside a wider picture of entrepreneurial reasoning. Sergeeva et al. (2021) describe how opportunities form and develop through analogy and abductive reasoning, and Darmayanthi et al. (2022) describe how mathematical knowledge can ground business development. Read together, they suggest a chain from generating a business idea, to representing the situation mathematically, to examining what alternative actions would bring. Neither article tests whether models improve business decisions, so the chain is a basis for the framework, not a result.

4.3. Cognitive and contextual processes in opportunity evaluation (RQ2)

The entrepreneurial cognition literature shows that recognizing and evaluating opportunities is neither fully objective nor linear. Judgments depend on how people attend to information, search for evidence, connect earlier experience to new situations, and read their context. In the socio-cognitive account, self-efficacy and outcome expectations raise opportunity recognition, and regulatory and normative institutional dimensions strengthen the self-efficacy path but not the outcome-expectation path (Camelo-Ordaz et al., 2020). Work on alertness, scanning, and information seeking moves attention to the processes that precede a decision. In that work a rational cognitive style mediates the link between alertness and decision effectiveness, while an intuitive style does not (Sassetti et al., 2022). Reviews of alertness connect the construct to recognition and to entrepreneurial outcomes (Chavoushi et al., 2021; Lanivich et al., 2022).

Configurational evidence points the same way. Evaluation outcomes arise from combinations of conditions, and no single condition acts as an absolute prerequisite (Andrade-Valbuena & Dos Santos, 2026). The discovery-creation debate adds that assessing an opportunity depends on the interplay between environmental conditions and the entrepreneur's actions (Chen et al., 2024), and a conceptual review calls for clearer definitions of what counts as an opportunity (Schlichte & Junge, 2025). In emerging economies, opportunity recognition mediates the path from cognitive and contextual factors to exploitation, with intelligence and social capital as moderators (Azam et al., 2026). Evaluation is therefore an interpretive process that combines information, experience, context, and judgments about uncertainty.

This matters for the use of models. A model can clarify relationships between factors and compare the consequences of different assumptions, but it does not capture social factors, tacit experience, or shifts in context unless someone puts them in. A model-based assessment must pair quantitative analysis with contextual interpretation. The quality of a decision depends on the quality of the data, the reasonableness of the assumptions, an understanding of uncertainty, and the ability to state the limits of the model, not on the accuracy of the calculation alone.

Individual and collective ability should also be separated. In a field experiment within an entrepreneurship education program, a balance between verbal and mathematical ability

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

within individuals was associated with team venture performance, and mixing members with different profiles did not offset an individual imbalance (Rosendahl Huber et al., 2020). This study lies outside the 12-article corpus, and its finding belongs to its original design.

Sergeeva et al. (2021) propose analogical abduction as a mechanism of entrepreneurial reasoning. Entrepreneurs frame a new situation through familiar experience, form conjectures about possible actions, and revise those conjectures after seeing the consequences. The idea matters here because evaluation rarely starts from complete quantitative data. Within this review, analogies and conjectures can be aligned with modeling: they shape an initial representation of an opportunity, and mathematical models then examine the quantitative implications of the assumptions behind it. The alignment is a conceptual synthesis made by this review and has not been tested empirically.

4.4. A conceptual framework for mathematical modeling as a cognitive tool (RQ3)

Examined separately, mathematics education and entrepreneurial cognition each explain only part of the process. The education literature suggests that entrepreneurial contexts can develop reasoning and analytical skill, and the cognition literature suggests that evaluation depends on how people interpret information and context. Combining the two leads to one proposition: modeling can act as a bridge that makes thinking visible through representations, assumptions, scenario comparisons, and reasoning that can be communicated (Andrade-Valbuena & Dos Santos, 2026; Camelo-Ordaz et al., 2020; Samsul et al., 2025; Sun & Yang, 2025).

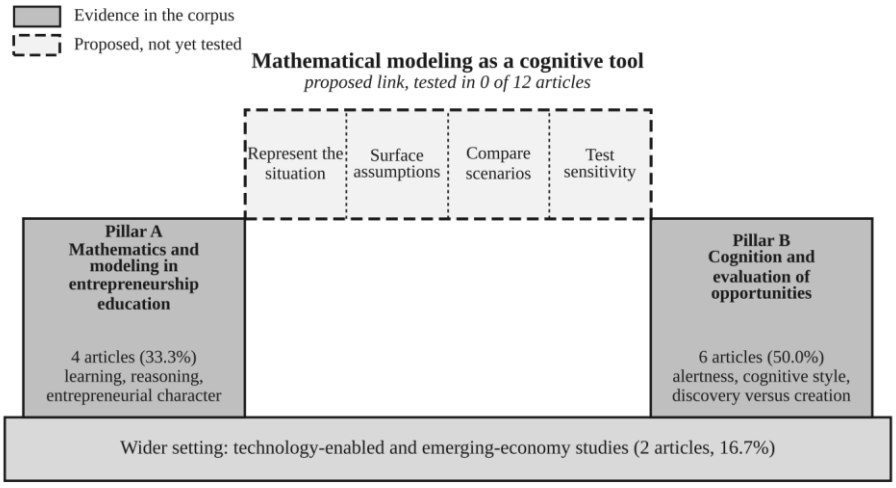


Figure 3: Conceptual Bridge Between Mathematics Education and Entrepreneurial Cognition

Figure 3 condenses the argument. Pillar A holds the four articles on mathematics and modeling in entrepreneurship education, Pillar B the six on cognition and opportunity evaluation, and the two studies on technology-enabled and emerging-economy settings form the wider context. Percentages are shares of the 12 included articles. The deck between the pillars is dashed because no included article tests it. The drawing is a conceptual device of this review, and pillar size reflects article counts, not the strength of evidence.

On this basis the review proposes a six-stage cycle (Fig. 4). Stage 1 frames the business problem or decision to be evaluated, and Stage 2 identifies variables, data, and assumptions, including missing information. Stage 3 mathematizes the situation in tables, graphs, equations, or functions, and Stage 4 compares scenarios and tests how results respond to changed assumptions. Stage 5 asks whether the results make sense in the business context and where the model stops being reliable. Stage 6 combines model results with market

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

information, experience, and risk to decide whether the opportunity should be tested, adjusted, or postponed.

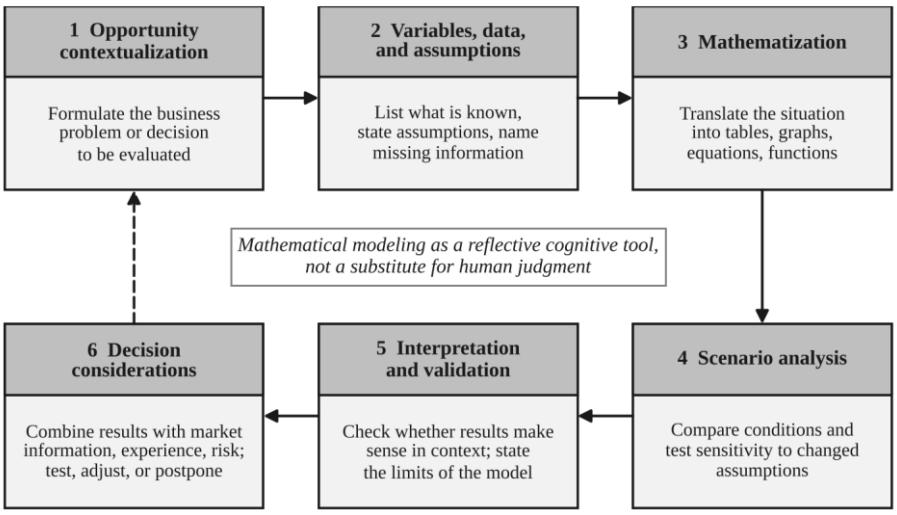


Figure 4: Six-Stage Conceptual Framework for Mathematical Modeling as a Cognitive Tool

Figure 4 places modeling as an aid to reflective reasoning and not as a decision-generating engine. The dashed arrow from Stage 6 back to Stage 1 marks the iterative character of the cycle: a decision to test or adjust an opportunity reopens the problem context. A model can reveal what follows from an assumption, yet a decision still has to deal with incomplete data, preferences, values, and institutional conditions. The framework is a conceptual synthesis of this review, and none of the 12 articles validated it empirically. Future validation should examine whether it improves problem representation, argumentation, risk comprehension, or the decisions of learners and aspiring entrepreneurs.

Its practical value lies in giving opportunity evaluation a structure: a guide for identifying variables, stating assumptions, analyzing quantitative scenarios, interpreting results, and justifying decisions. Its foundation is the published research on modeling, entrepreneurship education, and entrepreneurial cognition. Its effectiveness and its transfer across educational and entrepreneurial settings remain open questions.

4.5. Interpretation, implications, and limitations

Theoretically, the synthesis moves the question from whether mathematics is relevant to entrepreneurship toward how mathematics informs thinking when opportunities are evaluated. The shift matters because a general correlation between numeracy and business success cannot explain the relationship. A more specific contribution lies in the process: how problems are framed, assumptions are stated, alternatives are compared, and outcomes are interpreted. In this light modeling is an epistemic practice that connects quantitative evidence and judgment, and not only a technical skill.

The synthesis also exposes a tension between formalization and context. Models bring consistency and transparency, but their simplifications can overlook shifts in customer preferences, competitor behavior, and institutional conditions. Literature that stresses the contextual and interpretive nature of opportunities is a reminder that not every dimension of an opportunity can be turned into a variable without losing meaning (Chen et al., 2024; Schlichte & Junge, 2025). Model fragility is not hypothetical. A hybrid ARIMA–GARCH model fitted to monthly S&P 500 prices recorded a MAPE of 59.8% on the full sample and 13.0% once a structural break in 2009 was modeled separately (Mustapa & Ismail, 2026). Model literacy should therefore include the ability to tell when a model is useful, when it is fragile, and what further evidence it needs.

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

https://doi.org/10.35877/mathscience5520

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

Additional studies outside the coded corpus are cited for context only. Opportunity abandonment has been discussed in terms of errors in evaluating viable options (Arshi et al., 2024), and analytical and intuitive thinking styles in combination have been linked to fewer decision biases (Groves & Vance, 2025). Work on opportunity beliefs (Istanto & Indudewi, 2024) and a context-contingent stage theory (Quan, 2025) also bring cognition and situational conditions forward. Digital opportunities are assessed through how decision makers interpret possible actions (Ademi et al., 2023), and a survey of 329 digital start-up employees found that change leadership relates to sustainable performance partly through dynamic capability (Rahman et al., 2026).

For educators, the implication is to design tasks that assess the modeling process and not only the final answer. A learning scenario might ask students to calculate a break-even point, compare pricing scenarios, or estimate the effect of a change in demand, and then to justify their assumptions and state the limits of their predictions. Assessment could cover the choice of variables, the fit of the representation, the accuracy of the analysis, and the reasons given for the decision. Mathematical learning outcomes and opportunity evaluation should be measured as separate constructs (Hidayat et al., 2025; Samsul et al., 2025). Validation of materials is also a weaker step than testing them: expert ratings of a culture-based geometry e-module reached Aiken's V values of about 0.73, yet the study ran no classroom trial (Satriani et al., 2026).

For practitioners, a simple model can test initial feasibility and give team discussions a structure. Simulation and Value at Risk applied to two Indonesian stocks, for example, cut the maximum expected loss of a hypothetical IDR 100 million portfolio by more than half relative to holding one stock (Puspitaningtyas et al., 2025). The figure describes downside risk in market returns. It says nothing about whether a venture's demand assumptions hold. Precise-looking numbers do not make a prediction accurate when the data are weak or the assumptions unrealistic. Model results should therefore come with a range of scenarios, the data sources, and a statement of uncertainty. That practice lowers the risk of treating a quantitative output as settled fact and makes decisions easier to inspect.

The current literature does not provide a basis for concluding that mathematical modeling causally improves entrepreneurial success or the accuracy of opportunity evaluation. Many included articles discuss cognition or opportunity theory without testing modeling, and the educational articles focus on reasoning and learning more than on business outcomes. The main contribution of this review is a conceptual bridge and a set of testable propositions, not a claim of effectiveness.

Several limitations qualify the findings. The corpus is small and mixes empirical, conceptual, and review designs. No quality appraisal was applied, so the studies are described and not graded. The searches were restricted to English and Indonesian and to 2020–2026. The assignment of articles to clusters and the design labels in Table 2 are the authors' interpretation, and some articles could fit more than one cluster. The six-stage framework is a synthesis and has not been tested.

4.6. Future research agenda

Future empirical work should relate the quality of modeling to the quality of opportunity evaluation through experimental or quasi-experimental designs. Outcome measures should cover the quality of assumptions, estimates, risk identification, and argumentation, and the calibration of confidence in decisions. Studies should ask when scenario analysis, sensitivity analysis, or probabilistic modeling supports better decisions and when it creates false certainty, and should compare individual with collaborative modeling. Educational research needs instruments that separate mathematical competence, entrepreneurial literacy, and decision quality. Later reviews should document search dates, screening decisions, and full-text extraction, and should separate studies that test modeling directly from those that supply only a conceptual base.

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

5. Conclusion

This systematic review of 12 articles indicates that mathematical modeling has the potential to serve as a cognitive tool for evaluating entrepreneurial opportunities. It does so by identifying variables and assumptions, building mathematical representations, analyzing scenarios, and interpreting results in context. The synthesis yields a six-stage conceptual framework, from contextualizing an opportunity to weighing a decision, that positions modeling as an aid to reflective reasoning and not as a substitute for human judgment.

The evidence base limits the claim. The reviewed studies come mostly from education and entrepreneurial cognition, and none tests whether modeling improves the quality of opportunity evaluation. The framework is therefore a theoretically grounded proposal that needs empirical assessment, for example through studies that measure modeling quality, risk analysis, argumentation, and decision outcomes. In entrepreneurship education, modeling tasks should use contextual business problems and require learners to state assumptions, uncertainty, and data limits. Later reviews should report the search date, the screening decisions, and full-text-based extraction, so that the selection process can be checked by others. Given the interdisciplinary scope and the small number of included studies, the framework should not be treated as an established or generalizable intervention.

References

Ademi, P., Schuhmacher, M. C., & Zacharakis, A. L. (2023). Evaluating affordance-based opportunities: A conjoint experiment of corporate venture capital managers' decision-making. *Entrepreneurship Theory and Practice*, *47*(6), 2293–2322. https://doi.org/10.1177/10422587221134788

Andrade-Valbuena, N. A., & Dos Santos, M. A. (2026). Cognitive and contextual configurations in entrepreneurial opportunity evaluation: Insights from fsQCA. *BMC Psychology*, *14*(1), Article 203. https://doi.org/10.1186/s40359-025-03940-1

Arshi, T. A., Rao, V., & Butt, A. S. (2024). Opportunity abandonment: Why are entrepreneurs vulnerable to type I and II errors? *Heliyon*, *10*(9), Article e30094. https://doi.org/10.1016/j.heliyon.2024.e30094

Azam, S., Hussain, S., Muhamad, N., & Azam, H. (2026). Entrepreneurial opportunity recognition and exploitation in emerging economies. *Journal of Innovation and Entrepreneurship*, *15*(1), Article 28. https://doi.org/10.1186/s13731-026-00643-8

Bird, M. D., Reichert, P., & Farber, V. (2025). Risky business: Comparing the opportunity evaluation decisions of social and commercial entrepreneurs. *Economics Letters*, *256*, Article 112634. https://doi.org/10.1016/j.econlet.2025.112634

Camelo-Ordaz, C., Diánez-González, J. P., Franco-Leal, N., & Ruiz-Navarro, J. (2020). Recognition of entrepreneurial opportunity using a socio-cognitive approach. *International Small Business Journal: Researching Entrepreneurship*, *38*(8), 718–745. https://doi.org/10.1177/0266242620939843

Cevikbas, M., Kaiser, G., & Schukajlow, S. (2022). A systematic literature review of the current discussion on mathematical modelling competencies: State-of-the-art developments in conceptualizing, measuring, and fostering. *Educational Studies in Mathematics*, *109*(2), 205–236. https://doi.org/10.1007/s10649-021-10104-6

Chandra, A., Stewart, C. M., & Meyer, C. (2024). An eclectic problem-based learning model in an entrepreneurship capstone course. *The International Journal of Management Education*, *22*(3), Article 101034. https://doi.org/10.1016/j.ijme.2024.101034

Chavoushi, Z. H., Zali, M. R., Valliere, D., Faghih, N., Hejazi, R., & Dehkordi, A. M. (2021). Entrepreneurial alertness: A systematic literature review. *Journal of Small Business & Entrepreneurship*, *33*(2), 123–152. https://doi.org/10.1080/08276331.2020.1764736

Chen, J., Zhang, S. X., & Lundmark, E. (2024). A quantum view of entrepreneurial opportunity: Moving beyond the discovery and creation views. *Small Business Economics*, *63*(4), 1539–1553. https://doi.org/10.1007/s11187-024-00887-2

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

D'Angelo, V., Cavallo, A., Messeni Petruzzelli, A., & Frattini, F. (2026). Artificial intelligence and new venture creation: An entrepreneurial learning perspective. *Review of Managerial Science*. Advance online publication. https://doi.org/10.1007/s11846-026-01008-x

Darmayanthi, N. P. S. E., Putri, N. K. G. S., & Sumandya, I. W. (2022). Inovasi, dedukasi, edukasi (IDE) matematika landasan dalam membangun bisnis. *Emasains: Jurnal Edukasi Matematika dan Sains*. https://doi.org/10.5281/zenodo.7367379

Farman, Siswono, T. Y. E., Lukito, A., Dewi, R. S., Ndayizeye, O., & Hali, F. (2025). Mathematical creativity: A systematic review of current research on eye-tracking technology. *Journal of Applied Science, Engineering, Technology, and Education*, *7*(3), 451–464. https://doi.org/10.35877/454RI.asci4167

Geiger, V., Galbraith, P., Niss, M., & Delzoppo, C. (2022). Developing a task design and implementation framework for fostering mathematical modelling competencies. *Educational Studies in Mathematics*, *109*(2), 313–336. https://doi.org/10.1007/s10649-021-10039-y

Gonzalez-Tamayo, L. A., Maheshwari, G., Krauss-Delorme, C., & Bonomo-Odizzio, A. (2025). Startup decision-making: Integrating trial-and-error with the entrepreneur-as-scientist approach. *Journal of Small Business and Enterprise Development*, *32*(8), 169–196. https://doi.org/10.1108/JSBED-03-2025-0165

Groves, K. S., & Vance, C. M. (2025). Avoiding critical entrepreneurial cognitive errors through linear/nonlinear thinking style balance. *Journal of Small Business Management*, *63*(2), 872–898. https://doi.org/10.1080/00472778.2024.2363837

Gunawan, A., Rahim, A. R., Andriyansah, & Fatimah, F. (2025). Organizational agility based on automatic patch work behavior in the era of environmental uncertainty. *Journal of Applied Science, Engineering, Technology, and Education*, *7*(3), 392–410. https://doi.org/10.35877/454RI.asci4192

Hidayat, R., Ayub, A. F. M., Setambah, M. A. B. B., & Mazlan, N. H. (2025). A systematic review of the best practices for teaching mathematical modelling in education context. *European Journal of Science and Mathematics Education*, *13*(4), 255–272. https://doi.org/10.30935/scimath/17155

Istanto, A. A., & Indudewi, F. Y. R. (2024). Dispositional beliefs and opportunity beliefs as cognitive competence mediated by entrepreneurial mindset towards entrepreneurial behavior. *Jurnal Entrepreneur dan Entrepreneurship*, *13*(2). https://doi.org/10.37715/jee.v13i2.4798

Lanivich, S. E., Smith, A., Levasseur, L., Pidduck, R. J., Busenitz, L., & Tang, J. (2022). Advancing entrepreneurial alertness: Review, synthesis, and future research directions. *Journal of Business Research*, *139*, 1165–1176. https://doi.org/10.1016/j.jbusres.2021.10.023

Lidiana, V., & Sukestiyarno, Y. L. (2023). Development of entrepreneurship-based mathematical e-module and its' learning with PBL to improve students' mathematical problem solving ability. *Unnes Journal of Mathematics Education*, *12*(1), 93–102. https://doi.org/10.15294/ujme.v12i1.62911

Lin, G.-Y., Li, W.-H., & Wang, Y.-S. (2024). Developing and validating an instrument for assessing e-entrepreneurial idea feasibility. *The International Journal of Management Education*, *22*(3), Article 101060. https://doi.org/10.1016/j.ijme.2024.101060

Mustapa, F. H., & Ismail, M. T. (2026). Regime-adaptive ARIMA–GARCH framework under structural break: Evidence from the S&P 500 index. *Journal of Applied Science, Engineering, Technology, and Education*, *8*(2), 480–491. https://doi.org/10.35877/454RI.asci4894

Nurhikmah, H., Mappalotteng, A. M., Hakim, A., Dewi, L., Hidayanti, A., & Dewi, U. (2025). Cyberlearning model with microlearning strategies to enhance edutechpreneurship skills for university students. *Journal of Applied Science, Engineering, Technology, and Education*, *7*(3), 411–426. https://doi.org/10.35877/454RI.asci4363

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, Article n71. https://doi.org/10.1136/bmj.n71

Puspitaningtyas, A., Rosdiana, Hakim, L., & Zain, Y. (2025). Engineering-based investment modeling in emerging markets: Decision analytics for portfolio management in Indonesia. *Journal of*

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.

ISSN : 2776-7922 (Print) / 2807-3037 (Online)

Applied Science, Engineering, Technology, and Education, *7*(2), 242–255. https://doi.org/10.35877/454RI.asci3983

Quan, X. I. (2025). Towards a context-contingent stage theory of entrepreneurial opportunity: Introducing the PETII model. *Journal of Entrepreneurship and Innovation in Emerging Economies*, *11*(2), 204–224. https://doi.org/10.1177/23939575241291297

Rahman, Z., Abdullah, N. H., & Kistyanto, A. (2026). A study of digital start-ups: The mediating effect of employee dynamic capability on change leadership and sustainable employee performance. *Journal of Applied Science, Engineering, Technology, and Education*, *8*(2), 365–376. https://doi.org/10.35877/454RI.asci4815

Rosendahl Huber, L., Sloof, R., Van Praag, M., & Parker, S. C. (2020). Diverse cognitive skills and team performance: A field experiment based on an entrepreneurship education program. *Journal of Economic Behavior & Organization*, *177*, 569–588. https://doi.org/10.1016/j.jebo.2020.06.030

Samsul, P., Djafar, S., & Nurwijaya, S. (2025). Problem-project based learning model for improving entrepreneurship character and reasoning ability of mathematics education students. *Jurnal Riset Pendidikan Matematika*, *12*(2), 163–182. https://doi.org/10.21831/jrpm.v12i2.88122

Sassetti, S., Cavaliere, V., & Lombardi, S. (2022). The rhythm of effective entrepreneurs' decision-making process: The pathways of alertness scanning and search and cognitive style. A mediation model. *International Entrepreneurship and Management Journal*, *18*, 555–578. https://doi.org/10.1007/s11365-021-00759-1

Satriani, S., Sadijah, C., Sukoriyanto, Susanto, H., & Abdullah, A. H. (2026). Validity of e-module for mathematics learning within the Ammatoa cultural context that enhances students' creative thinking skills. *Journal of Applied Science, Engineering, Technology, and Education*, *8*(2), 466–479. https://doi.org/10.35877/454RI.asci4704

Schlichte, F., & Junge, S. (2025). The concept of entrepreneurial opportunities: A review and directions for future research. *Management Review Quarterly*, *75*(4), 3699–3725. https://doi.org/10.1007/s11301-024-00466-5

Sergeeva, A., Bhardwaj, A., & Dimov, D. (2021). In the heat of the game: Analogical abduction in a pragmatist account of entrepreneurial reasoning. *Journal of Business Venturing*, *36*(6), Article 106158. https://doi.org/10.1016/j.jbusvent.2021.106158

Sun, Y., & Yang, M. (2025). Teaching strategy of innovation and entrepreneurship education and mathematical modelling course integration based on cluster analysis. *Systems and Soft Computing*, *7*, Article 200388. https://doi.org/10.1016/j.sasc.2025.200388

Wei, Y., Long, D., & Fu, L. (2024). The influence of intuitive-analytical cognitive styles on entrepreneurial decision-making logic: Moderated by environmental uncertainty. *SAGE Open*, *14*(3). https://doi.org/10.1177/21582440241273297

Yani, S., & Suryawan, I. P. P. (2025). Hubungan kewirausahaan dan pembelajaran matematika: Systematic literature review. *Emasains: Jurnal Edukasi Matematika dan Sains*, *14*(2), 168–181. https://doi.org/10.59672/emasains.v14i2.5097

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC) 4.0 license.