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Computational and Simulation-Based Learning in Financial Mathematics Education: A Scopus-Based Scoping Review

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Abstract:
Computational tools can make financial relationships manipulable and visible, but evidence about their educational use remains fragmented. This Scopus-based scoping review mapped approaches, pedagogy, learning evidence, and gaps in financial mathematics education. Following JBI-informed procedures and PRISMA-ScR, Scopus was searched on 10 November 2026 for English-language journal articles from 2015–2026. Of 29 records, 17 full texts were assessed; 15 publications represented 14 linked evidence families. Common approaches included spreadsheets/simulators, web applications, and programming tools (three publications each), and computational laboratories (two). Applied problem solving appeared in 12 publications; programming/model construction and parameter exploration in six each, with overlap. Eight publications were provisionally coded for evaluation questionnaires; two linked Barana publications collected questionnaire-based learning-process data. Three publications reported heterogeneous financial-mathematics tests or performance, and one provided observed or written-task evidence; only one used a concurrent comparator. Two publications reported effect sizes, which do not establish a general causal advantage. Delayed financial-mathematics retention, transfer, and outcome-test validation remain incompletely verified. The synthesis supports alignment of content, computational practice, pedagogy, and assessment. However, the available evidence does not yet establish their general effectiveness in improving learning outcomes. Future research should prioritize validated direct assessments, comparative designs, delayed retention and transfer tasks, and replication across educational contexts.

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Introduction (مقدمة)

Financial mathematics requires learners to connect time, cash flows, rates, uncertainty, and model assumptions. Computational environments can expose these relationships through parameter variation, visual representations, simulation, and code. Their pedagogical value nevertheless depends on what students do with the technology. A spreadsheet that merely returns an answer supports a different form of learning from a program that students construct, test, debug, and interpret. In the included literature, bond valuation and duration are represented through Maple documents (Petrášková & Rosa, 2019), while derivatives pricing is implemented through numerical models and Python code (Varma & Virmani, 2016). These examples motivate examining the relationship between mathematical representation and learner activity.

The field also spans very different levels of mathematical demand. Introductory courses address interest, savings, discount, debt, and amortization, whereas computational-finance courses use stochastic models, derivatives pricing, Monte Carlo methods, volatility models, and risk measures. These differences make a tool-only summary misleading. A useful educational synthesis must connect mathematical content, computational practice, instructional design, and the evidence used to judge learning. The contrast is illustrated by the amortization activities of Martins and de Assis Olgin (2019) and the R-based financial-modeling course described by Yan (2017).

Computational participation can also vary within the same software environment. Learners may enter values into a prepared interface, translate a formula into a spreadsheet, modify a parameter in a dynamic document, write and test code, or interpret a simulation under uncertainty. Each activity places different demands on conceptual knowledge and computational thinking. Tool availability therefore cannot serve as a proxy for learner agency. The central analytical question is whether the instructional task makes mathematical structure, assumptions, and consequences available for examination. Broader higher-education evidence indicates that simulation design and instructional support should be considered together: Chernikova et al. (2020, Discussion) relate the usefulness of examples and reflection to learners' prior knowledge. That finding supports attention to pedagogical design here; it does not establish an effect for this financial-mathematics corpus.

Varma and Virmani (2016) describe numerical derivatives pricing through QuantLib-Python, while Yan (2017) describes finance-oriented programming exercises and projects. These course accounts make computational practice relevant to financial-mathematics education, but neither a course description nor the availability of professional software alone establishes a learning gain. Consequently, it remains unclear how consistently the reported educational benefits of computational tools are supported by robust empirical evidence. The review therefore examines both the activity offered to learners and the evidence used to evaluate it.

Earlier reviews provide adjacent but different perspectives. Saini and Rosli (2021) synthesized 30 empirical publications from 2011–2019 across five databases, focusing on financial-literacy elements and teaching methods in primary and secondary mathematics. Serrano Layana (2026) reviewed 15 open-access articles from 2021–2026 across four information sources, examining educational technologies in higher-education financial mathematics and noting heterogeneous methods and frequent reliance on perception measures. The present review does not claim to be the first. Its distinct contribution is an integrated mapping of financial-mathematical content, computational practice, documented learner activity, and the form and limitation of learning evidence. This four-layer synthesis permits pedagogical affordances to be distinguished from measured outcomes and prevents tool availability or positive perception from being treated as proof of learning effectiveness.

The review addressed four questions:

RQ1. What computational and simulation-based approaches have been used to teach financial mathematics, and which mathematical concepts are addressed?

RQ2. How are computational tools and mathematical simulations integrated into learning activities, instructional designs, and assessment practices?

RQ3. What learning outcomes and forms of empirical evidence have been reported, and what methodological limitations affect their interpretation?

RQ4. What research gaps and future directions emerge from the relationships between mathematical content, computational approaches, pedagogical implementation, and evaluation practices?

Method (منهج)

Review design and eligibility

A Scopus-based scoping review was conducted using JBI-informed procedures and reported with PRISMA-ScR (Aromataris et al., 2024; Pollock et al., 2026; Tricco et al., 2018). The population was learners or prospective educators in formal education; the concept was substantive computation or simulation connected to financial mathematics; and the context included secondary, higher, professional, or teacher education. Eligible sources were English-main-text journal articles or reviews published from 2015 through 2026. Incidental mentions of software, noneducational finance papers, conference material, and non-English main texts were excluded (Table 1). No prospectively registered protocol was identified in the records consulted; no protocol registration is claimed.

Information source and search

Scopus was searched on 10 November 2026. The complete string is reproduced in Supplementary Document S1. The operational search returned 29 records. A preceding 71-record pilot search informed query refinement but was not included in the PRISMA denominator. The review did not search multiple databases. Targeted backward and forward checks used publisher reference lists, public citation pages, and OpenAlex for selected seed studies. Those checks were supplementary and partial; no complete Scopus cited-by export or exhaustive reference-list screening was performed.

Selection and verification

The sole author screened 29 Scopus records and assessed 17 reports at full text; 12 records were excluded at title/abstract screening. An additional contributor then performed a non-blinded, source-guided comparison of the initial decisions and structured summaries, with earlier decisions available during the check. The comparison matched 29/29 initial record decisions, 17/17 initial full-text decisions, and 15/15 summaries from the pre-reconciliation extraction set. These results do not represent independent duplicate screening or extraction, nor agreement statistics for the reconciled corpus. Subsequent source-level eligibility reconciliation included Yan (2017), whose R-based course documented learner financial-modeling activities, and excluded a Spanish-main-text article initially indexed with English metadata; an overview without learner computational activity remained excluded. These changes affected the composition but not the number of included publications. Yan was charted from the original source after the comparison and therefore was not part of the earlier 15/15 summary check. The sole author retained final responsibility for eligibility and synthesis decisions. The reconciliation chronology is recorded in the supplementary ledger.

Data charting and synthesis

For each included publication, data were charted on content, tool, learner activity, design, sample, instrument, comparator, outcome, limitation, and source locator. NR denotes an applicable item not adequately reported following source-level review, whereas NA indicates that an item did not apply to the study design or aim; not verified indicates that available documentation was insufficient to reach a reliable decision. Publications (n = 15) were the denominator for descriptive counts, except when the 14 related evidence families were explicitly considered. Dominant context, design, technology, and content categories were mutually exclusive for profile counts; pedagogical-practice and evidence categories were multi-label and could sum to more than 15. Percentages used the number of publications in each category divided by the applicable denominator. Heterogeneous outcomes were not pooled, and findings that could not be established from the accessible source documentation remained not verified rather than being treated as unreported. The synthesis connected four layers: mathematical content, computational practice, pedagogy, and learning evidence.

Interpretive safeguards

Tool-development, teaching-implementation, perception-based, process-oriented, and learning-outcome publications were not treated as equivalent evidence. A design paper could establish what mathematical activity a tool enables but not whether learning improved. A positive perception could indicate acceptability without demonstrating conceptual change. Predictive models fitted within one setting were interpreted as associations rather than causal effects. Claims were retained only when a full-text locator supported the charted information; an applicable but unreported item was coded NR, while insufficiently established information was coded not verified. These safeguards were applied before cross-study synthesis and carried into the wording of Results and Discussion.

Table 1. Eligibility criteria and PCC framework

No	Dimension	Information	Excluded
1	Population	Learners or prospective educators in formal education	Finance professionals without an educational activity
2	Concept	Substantive computation or simulation connected to financial mathematics	Incidental technology or no learner mathematical activity
3	Context	Secondary, higher, professional, or teacher education	Noneducational settings
4	Source	English-main-text journal articles/reviews, 2015-2026	Non-English main text, conference proceedings, non-journal sources

Result (نتائج)

Study selection and profile

The search produced 29 records; 12 title/abstract exclusions and two full-text exclusions yielded 15 included publications and 14 evidence families (Figure 1; Table 2). Publication years ranged from 2015 to 2026, with nine publications (60.0%) appearing from 2020 onward. Twelve publications (80.0%) concerned higher education, two (13.3%) pre-service teacher education, and one (6.7%) had an educational level that remained unclear in the charted source. Designs comprised five course-design or implementation reports, five single-group perception or

predictive evaluations, two process-oriented computational-laboratory studies, one didactical-engineering study, one sequential nonrandomized study, and one concurrent controlled mixed-methods study. The corpus therefore maps educational uses more strongly than it estimates comparative effectiveness.

Table 2. Characteristics and evidence types of the 15 included publications

Included publication	Learner context / design	Financial content and tool	Evidence reported
Salas-Rueda (2021)	29 Marketing students; flipped, single group	Simple interest; spreadsheet, videos, Drive	Perceptions and predictive associations
Petrášková & Rosa (2019)	Pre-service teachers; design report	Bond value and duration; MapleCloud	Interactive demonstrations; learning gain NR
Salas-Rueda et al. (2020)	46 undergraduates ; one-group evaluation	Compound interest; WAEPCI web app	Predictive associations; no causal estimate
Martins & de Assis Olgin (2019)	24 undergraduates ; didactical engineering	Amortization; HP 12C emulator	Group task observations/written work; effect size not verified
Varma & Virmani (2016)	Finance-course learners; n NR	Derivatives and Monte Carlo; QuantLib-Python	Teaching implementation; outcome instrument NR
Barana et al. (2023)	50 students; computational lab cohort	Computational finance; coding labs	396 weekly questionnaire responses; process-phase coding*
Yan (2017)	Finance students; course-design report	PV, Black–Scholes, portfolios; R	Hands-on projects; measured improvement NR
Hernández Moreno et al. (2021)	103 analyzed; nonrandomized sequence	Simple interest; SICMAR mobile AR	Five-item pre/post practice tests, separate surveys; reported d = −0.427
de la Puente et al. (2026)	300 students; 32-week controlled study	GARCH, options, risk; QuantLib	Performance effect reported in publisher abstract; instrument detail not verified
García-Santillán et al. (2015)	Participants NR; tool design	Debt restructuring; spreadsheet simulator	Demonstration; measured learning NR
Barana et al. (2026)	22 students; historic cohort comparison	Computational finance; collaborative labs	176 questionnaire responses; historical process comparison*

Salas-Rueda (2020)	42 students; single-group evaluation	Simple discount; WATLSD web app	Predictive associations; causal effect NR
Slavíčková (2021)	25 pre-service teachers; short-interval FM pre/post tasks	Financial-mathematics tasks; digital technology	FM pre/post written-task evidence; validation not verified
Salas-Rueda & Alvarado-Zamorano (2022)	43 students; one-group evaluation	Bank savings; WATLPBS web app	Predictive associations; causal effect NR
García-Santillán & Molchanova (2018)	52 Business School students; survey	Financial mathematics; Excel/simulators	Perception/factor-analysis findings

Note. NR = not reported after source-level checking; not verified remains distinct from NR; AR = augmented reality; FM = financial mathematics. *Barana et al. (2023) analyzed 396 weekly questionnaire responses but recorded 402 phase occurrences because a response could receive more than one phase code (Section 4.1, Table 2). The linked 2026 publication uses a historical cohort; the two form one evidence family.

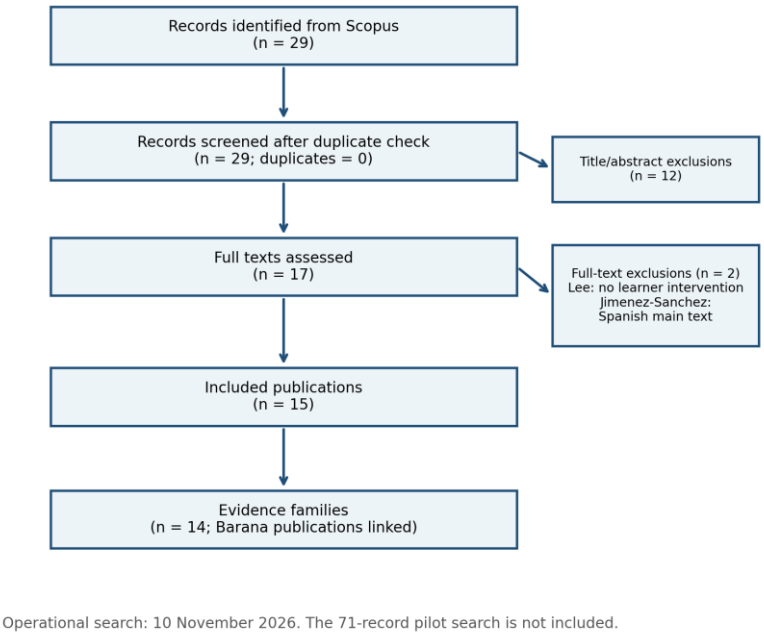

Figure 1. PRISMA-ScR flow for the operational Scopus search.

RQ1. Computational approaches and financial-mathematics content

Three dominant computational-environment groups each contained three publications: spreadsheets or financial simulators, web applications or virtual spaces, and programming languages or open-source libraries. Two publications examined collaborative computational laboratories, while Maple, a calculator emulator, mobile augmented reality, and a multiple-

technology teacher-education implementation appeared once each. Introductory content was most common: interest, discount, or savings was the dominant content in five publications, and amortization or debt in two. Three publications addressed advanced derivatives, stochastic modeling, portfolios, or risk; two addressed broad computational finance; two addressed broad financial-mathematics or teacher-preparation content; and one focused on bonds. Accessible interfaces therefore supported rate and cash-flow relationships, whereas R and QuantLib supported model construction, simulation, derivatives, and risk. Across the included studies, technology choice tracked the mathematical object made available for inspection, but no tool category had comparable evidence sufficient for an effectiveness ranking.

RQ2. Pedagogical integration, instructional activity, and assessment

Applied problem solving or financial calculation was documented in 12 publications. Parameter exploration, simulation, or interactive visualization appeared in six; programming, model construction, or debugging in six; and collaborative, presentation, or peer activity in five. Flipped preparation and pre-service teacher design each appeared once. These categories were not mutually exclusive. The same spreadsheet could support passive answer production or active comparison of assumptions, while code-based laboratories could combine model construction, visualization, debugging, and group explanation. Assessment practices did not consistently match those learner actions: several implementations described rich computational activity but assessed acceptability or provided no measured learning outcome. The pedagogically meaningful unit was thus the documented learner action, not the software label. Hernández Moreno et al. (2021), de la Puente et al. (2026), and Slavíčková (2021) reported different tests or written-performance tasks; Martins and de Assis Olgin (2019) described group observation and written work. These four publications were not interchangeable standardized learning-gain studies. The two linked Barana studies coded weekly questionnaires for learning processes rather than satisfaction or direct observation, underscoring the distinction between data source and measured construct.

RQ3. Forms of learning evidence

The evidence categories overlapped. Eight publications were provisionally classified as using educational-evaluation questionnaires; this does not imply eight validated satisfaction or learning-gain studies. Two linked Barana studies coded weekly questionnaires for process analysis, yielding ten publication-level questionnaire-data instances but not ten satisfaction studies. Four publications described implementation without measured learning outcomes, and four used process, log, or observational evidence. Tests or performance measures appeared in three studies (Hernández Moreno et al., 2021; de la Puente et al., 2026; Slavíčková, 2021), with separate observation or written-task evidence in Martins and de Assis Olgin (2019). Three studies reported motivation or collaborative engagement. The only concurrent controlled comparison was de la Puente et al. (2026); Hernández Moreno et al. (2021) used a nonrandomized sequence and Barana et al. (2026) a historical cohort. These designs were not pooled.

RQ3. Evidentiary limitations and strength of conclusion

Perception questionnaires can assess usability, satisfaction, or self-reported learning, not necessarily objective improvement. Barana et al. (2023, 2026) coded weekly questionnaires for collaborative processes, not achievement. Heterogeneous task evidence comprised tests or performance measures (Hernández Moreno et al., 2021; de la Puente et al., 2026), short-interval pre/post written tasks (Slavíčková, 2021), and group observation or written work (Martins & de Assis Olgin, 2019). Standardized comparability remains unverified. Hernández Moreno et al. (2021) reported paired $d = -0.427$; the publisher abstract of de la Puente et al. (2026) reported $d = 1.42–2.17$. These effects were not pooled and do not establish corpus-wide causal efficacy.

Cronbach coefficients in Hernández Moreno et al. (2021, Table 4) concern questionnaires, not achievement-test validation, which remains insufficiently verified.

Cross-RQ integration: content, computation, pedagogy, and evidence

Across the four layers, stronger alignment was visible when a mathematical relationship was connected to an inspectable computational action and assessed with evidence suited to that action. For example, parameter variation could expose sensitivity, programming could reveal assumptions and reproducibility, and collaborative code or graphs could support explanation and revision. However, an interface could also hide the mathematical model, and a favorable questionnaire could coexist with unmeasured performance. The synthesis-derived framework in Figure 2 therefore represents a design-and-evidence alignment proposition rather than an empirically validated causal model.

RQ4. Empirical gaps and future research directions

Four publications lacked usable participant sample sizes in the available charting (Petrášková & Rosa, 2019; Varma & Virmani, 2016; Yan, 2017; García-Santillán et al., 2015); Slavíčková (2021) included 25 financial-mathematics participants. Educational level was unclear in one record. Delayed financial-mathematics retention and transfer to unfamiliar problems could not be established consistently from available documentation; absence is not assumed. The three-month delayed test in Slavíčková (2021) concerned calculus, while financial mathematics was assessed through short-interval pre/post written tasks (Section 5.2). Four publications supplied heterogeneous non-self-report task evidence, and only one used a concurrent comparator. No secondary-level publication remained after applying the English-main-text criterion. Actuarial contingencies, insurance mathematics, credit risk, and sustained portfolio learning were sparsely covered. Validation of direct learning instruments remains insufficiently verified. The priorities are transparent assessment, comparative designs, delayed measures, and transfer tasks.

Discussion (مناقشة)

The synthesis shows that computation functions as a representational and modeling medium rather than as an educational intervention in itself. Introductory environments reduced calculation burden and made rate, period, or cash-flow relationships manipulable; programming environments exposed algorithms, assumptions, uncertainty, and reproducibility. The pedagogical consequence depends on whether learners merely execute a prepared procedure or construct, test, explain, and criticize a model. This distinction explains why the 12 publications with applied problem solving cannot be interpreted as 12 comparable demonstrations of effectiveness.

A mismatch emerged between computational activity and evaluation. Six publications documented programming or model construction and six parameter exploration, but only three reported heterogeneous financial-mathematics tests or performance measures (Hernández Moreno et al., 2021; de la Puente et al., 2026; Slavíčková, 2021); Martins and de Assis Olgin (2019) also documented group observation or written tasks. Eight provisional educational-evaluation questionnaire codes differed from the two linked Barana studies' process-coded questionnaires; four design-oriented publications lacked measured learning outcomes in the available charting. Favorable experience or engagement cannot establish conceptual improvement. Evidence is stronger for feasibility and participation than for causal claims. Hernández Moreno et al. (2021) reported change across a nonrandomized instructional sequence, while the Salas-Rueda web-application evaluations largely relied on questionnaire variables and predictive associations. These outcomes are not interchangeable estimates of effectiveness.

The findings also clarify why a technology ranking would be scientifically inappropriate.

Spreadsheets, web applications, computer algebra, emulators, augmented reality, and programming libraries can each support either active reasoning or passive execution. Differences in learner background, mathematical content, duration, task design, comparator, and outcome measure are too substantial for cross-tool effect comparisons. The relevant evaluative question is therefore whether the computational affordance, learner activity, and assessment are aligned with the intended mathematical reasoning.

Collaborative computational laboratories illustrate this alignment particularly clearly. Code, graphs, failed runs, and parameter choices create artifacts that peers can examine and revise. The two Barana publications provide questionnaire-derived process evidence from linked cohorts and represent one evidence family for independence-sensitive synthesis. Barana et al. (2023, Section 4.1, Table 2) analyzed 396 weekly responses and 402 phase occurrences because individual responses could receive multiple codes. Barana et al. (2026) analyzed 176 later-cohort questionnaire responses and compared process patterns with a historical cohort. Neither study supplies a directly measured standardized achievement effect, and their process findings cannot be pooled as an attainment estimate.

Relative to previous reviews, the contribution is one of analytical integration rather than chronological novelty. Saini and Rosli (2021) established a broader school financial-literacy landscape, while Serrano Layana (2026) synthesized educational technologies in higher-education financial mathematics. This review adds an auditable mapping from financial content to computational action, pedagogical implementation, and evidence type, including explicit separation of publication counts from linked evidence families and of NR from NA and not verified. The resulting framework is useful for designing and evaluating instruction, but it remains synthesis-derived and requires prospective testing.

The empirical gap supports a specific research agenda. Comparative studies should contrast computational and non-computational instruction while holding content and instructional time constant; delayed tests should examine retention; unfamiliar financial problems should test transfer; and direct reasoning rubrics should be paired with software-output checks. Collaborative programming studies should examine the quality of explanation, model revision, and individual attainment after group work. Multi-site replication is needed across secondary, university, teacher-education, and professional contexts, with pre-specified outcomes and transparent instrument evidence. These recommendations address demonstrated reporting and design gaps rather than assuming that any computational intervention is already effective.

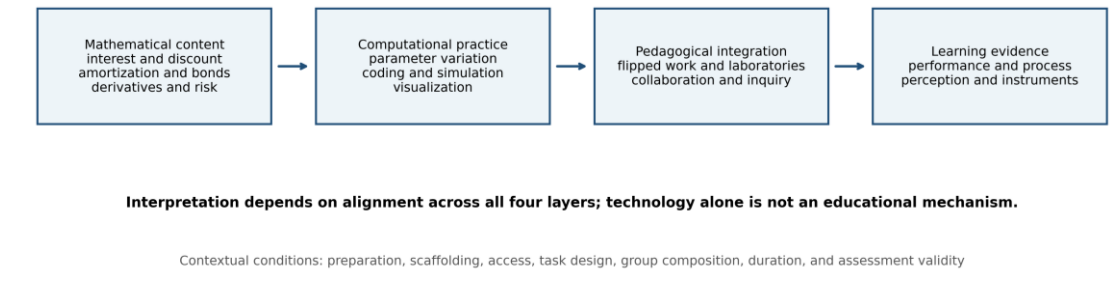

Figure 2. Synthesis-derived framework linking content, computational practice, pedagogy, and evidence.

Conclusion (خاتمة)

The review answers RQ1 by mapping computational approaches from spreadsheets and web applications for interest and savings to programming for stochastic modeling, derivatives, and risk. RQ2 shows that the relevant pedagogical unit is learner activity: parameter exploration, model construction, debugging, explanation, and collaboration. For RQ3, evidence is concentrated in perceptions, descriptions, and process coding, alongside three publications with heterogeneous financial-mathematics tests or performance (Hernández Moreno et al., 2021; de la Puente et al., 2026; Slavíčková, 2021), one with observational or written tasks (Martins & de Assis Olgin, 2019), and one concurrent comparator. RQ4 identifies the need for stronger instruments, comparative designs, delayed retention and transfer assessment, replication, and broader topic coverage. The synthesis-derived framework links content, computation, pedagogy, and evidence, but is not a validated causal model. The findings provide an auditable design-and-evidence map, not a general technology-effect estimate.

Implications for Teaching and Learning

Instructional design should begin with the financial-mathematical reasoning to be demonstrated, not with the availability of a tool. Tasks should require learners to expose assumptions, compare models, interpret outputs, and justify decisions. Assessment should match that activity through transparent performance tasks, code or model inspection, written reasoning, and, where appropriate, collaborative-process evidence. Perception measures remain useful for implementation but should be reported separately from learning performance. A staged curriculum can move from tool-supported calculation to parameter exploration, model construction, uncertainty analysis, and model criticism while retaining checkpoints for mathematical reasoning independent of software execution.

Limitations

This review used Scopus only, restricted eligibility to English-main-text journal publications, and covered 2015–2026. Citation searching was targeted rather than exhaustive, and no prospective protocol registration was identified in the available records. Screening and extraction were conducted by the sole author; the subsequent comparison was non-blinded, source-guided verification and did not constitute independent duplicate screening or extraction. Some source-level reporting was uneven, and assessment-instrument validation status was not systematically charted. Full-text verification of absence claims for effect sizes, delayed retention, and transfer remains incomplete in the current evidence archive; these items are therefore not asserted as confirmed NR. The Barana publications are linked and were treated as one evidence family when independence mattered. Descriptive coding inevitably simplifies multi-tool and multi-activity studies, although publication IDs and rules are retained in the supplementary matrices. Formal methodological quality appraisal was not undertaken, consistent with the mapping purpose; design and evidence limitations were instead characterized publication by publication. Findings should therefore be read as a map of a bounded Scopus corpus, not an exhaustive estimate of technology effectiveness.

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