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Dedication

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Academic Journal of Research and Scientific Publishing

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The Intellectual Structure of Research on Agentic AI Ethics and Governance in Higher Education: A Systematic Evidence Synthesis and Research Agenda

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Abstract:

Research on the ethics and governance of artificial intelligence in higher education has expanded rapidly since 2022, but the field's intellectual structure, its dominant themes, internal debates, and blind spots have not been systematically mapped since AI tools began exhibiting agentic properties such as multistep planning and autonomous task execution. This evidence synthesis maps the field using a PRISMA guided systematic search and bibliometric analysis of 312 publications (2019 to 2026) drawn from Web of Science and Scopus. Keyword co-occurrence and co-citation analyses identify five thematic clusters: transparency and explainability; distributed accountability and liability; human oversight and controllability; value alignment and epistemic integrity; and equity, access, and algorithmic fairness. For each cluster, the synthesis characterizes the constituent literature, its convergent findings, and its unresolved disagreements. Across clusters, six structural gaps emerge: a deficit of empirical implementation studies relative to conceptual work; the absence of validated measurement instruments for responsible AI use; the underrepresentation of community colleges, minority-serving institutions, and Global South contexts; an imbalance that favors accountability directed at students over accountability directed at institutions and developers; uncertain transfer of findings from before 2023 to agentic systems; and a weak connection between education research and technical AI governance venues. The paper concludes with a research agenda addressing each gap in turn, intended to guide researchers, editors, and funders as agentic AI deployment in higher education accelerates.

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Keywords: bibliometric analysis, academic integrity, institutional policy, accountability, equity

1. Introduction:

The arrival of generative AI in higher education produced one of the fastest growing literatures in educational research. Within three years of ChatGPT's release, scholarship on the ethics and governance of AI in universities had moved from a specialist concern to a mainstream preoccupation of journals across educational technology, higher education studies, and applied ethics. Rapid growth of this kind carries a familiar cost: literature accumulates faster than anyone can read it, duplicated effort proliferates, and the questions that matter most are not necessarily the questions being studied. Periodic systematic mapping is the discipline's corrective. Existing syntheses, however, either predate the field's turn toward agentic AI, systems that plan, execute, and adapt multistep tasks with limited human oversight, or address single slices of the problem, such as academic integrity (Bittle & El-Gayar, 2025) or AI ethics in education generally (Yu & Yu, 2023). No published synthesis has mapped the full ethics and governance literature as it has reorganized itself around agentic capabilities.

This paper provides that map with three questions. First, what is the intellectual structure of research on the ethics and governance of AI in higher education between 2019 and 2026: which themes organize the field, which works anchor them, and how has the structure shifted over time? Second, within each thematic cluster, what has the literature established, and where does it disagree? Third, what does the field systematically fail to study, and what research agenda follows from those gaps?

The corpus analyzed here was originally assembled for a companion study (Author, 2026, manuscript submitted for publication) that used bibliometric clustering instrumentally, as the empirical foundation for a governance framework. The present paper has a different purpose and makes a different contribution: the synthesis itself. Where the companion paper asks how institutions should govern agentic AI, this paper asks what the research field knows, how that knowledge is organized, and where it is thin. What this paper offers instead is the field level evidence assessment that framework building necessarily compresses: a cluster by cluster reading of the literature's composition and quality, an explicit gaps analysis, and a prioritized agenda for the next phase of research.

1.1. Purpose and Significance of the Study

This study provides the first systematic, PRISMA guided map of ethics and governance literature since AI tools in higher education began exhibiting agentic properties. Its purpose is threefold: to identify the thematic clusters, anchor works, and points of agreement and disagreement that organize the field between 2019 and 2026; to expose the structural gaps, in measurement, implementation evidence, institutional representation, and accountability balance, that the field has not yet addressed; and to translate those gaps into a prioritized research agenda.

The significance of this synthesis extends beyond a literature review. As agentic AI systems assume greater autonomy over academic tasks, institutions, regulators, and funders are already making governance decisions on the strength of literature this paper shows to be conceptually mature but empirically thin. By identifying exactly where the evidence base is strongest and where it is weakest, this study equips researchers to direct their next studies productively, gives editors and reviewers a basis for raising the field's evidentiary standards, and gives funders and institutional leaders a concrete, prioritized target for investment.

2. Background: The Agentic Turn in Educational AI

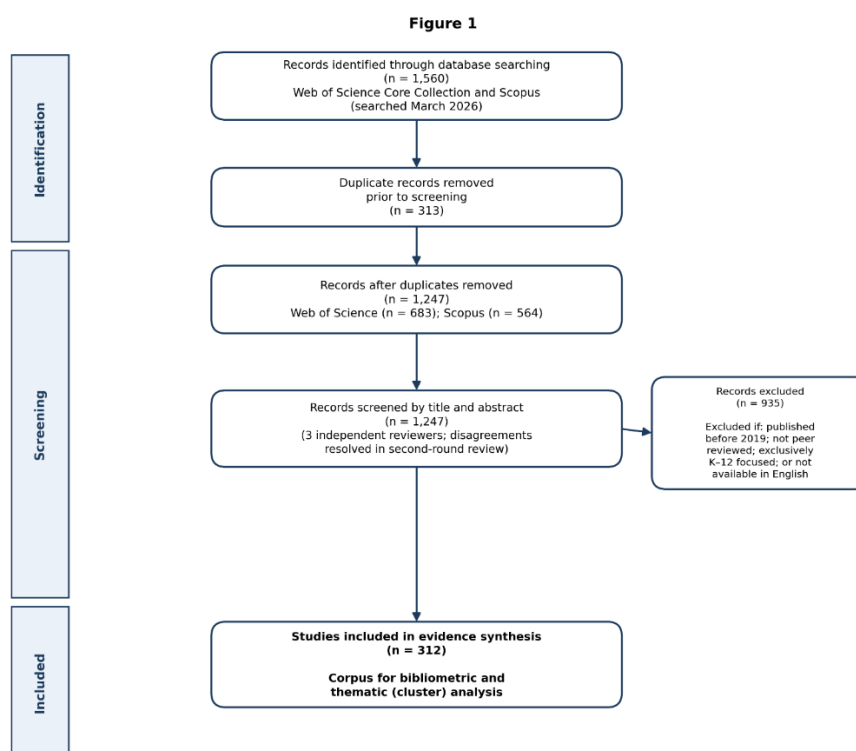
Two developments make this systematic literature review timely. The first is empirical. Adoption of generative AI in higher education outran both policy and research almost immediately: by late 2023, nearly half of American high school students reported using generative AI for schoolwork (ACT, 2023), while many educators reported working without clear institutional AI policies, and a quarter of higher education institutions surveyed globally had already encountered ethical incidents related to AI (UNESCO, 2025). Evidence on learning effects accumulated just as quickly and just as unevenly: meta-analyses report a moderate-to-large positive effect of ChatGPT use on achievement (Liu et al., 2025) and a large positive effect on undergraduate learning outcomes (Mo et al., 2026), yet primary studies caution that effects reverse when AI substitutes for rather than scaffolds student reasoning (Imran & Almusharraf, 2023), and research on student voice reveals simultaneous enthusiasm and anxiety about dependency and fairness (Baidoo-Anu & Owusu Ansah, 2023; Chan & Hu, 2023).

The second development is conceptual. The ethics literature's object of study changed underneath it. Early work addressed reactive systems, tools that answer prompts, inheriting its categories from the AI literacy tradition (Long & Magerko, 2020; Ng et al., 2021). Beginning around 2024, a new theoretical vocabulary entered the field through work on advanced AI assistants (Gabriel et al., 2024) and the dimensional characterization of AI agents by autonomy, efficacy, goal complexity, and generality (Kasirzadeh & Gabriel, 2025). Systems now common in universities occupy the lower reaches of this agentic spectrum: they decompose assignments, carry context across sessions, and act on a student's behalf across tasks. Whether the findings and frameworks built for reactive tools survive this transition is, as the synthesis below shows, one of the field's most consequential open questions. Institutions, meanwhile, are governing in the interim: policy inventories find enormous variation in scope and enforceability across universities (Azevedo et al., 2025), and global survey data indicate that only about a fifth of institutions have formal AI policies while twice that share report frameworks still under construction (UNESCO, 2025). The literature mapped below is therefore not an academic exercise; it is the evidence base on which a live, worldwide effort to build policy is drawing.

3. Methodology:

3.1. Search Strategy and Screening

Records were retrieved from the Web of Science Core Collection and Scopus in March 2026 using a Boolean string combining three concept groups: AI ("agentic AI" OR "generative AI" OR "large language model*" OR "LLM"), setting ("higher education" OR "universit*" OR "academic*"), and governance ("ethic*" OR "governance" OR "accountabilit*" OR "responsibilit*"), with truncation wildcards to capture variant word forms. The search using key words and combination of keywords was conducted in title, abstract, and text of the literature. Eligible records were peer-reviewed journal articles, conference papers, editorials, books and book chapters. other non-peer-reviewed materials were excluded. Before deduplication, 1,560 records were retrieved; 313 duplicates were identified and removed by Doi matching and content scanning. The search returned 1,247 unique records after deduplication (WoS: 683; Scopus: 564). Screening followed PRISMA 2020 procedures: records were excluded if published before 2019, not peer reviewed, exclusively K–12 focused, or unavailable in English, yielding a final corpus of 312 articles/literature. Title and abstract screening were conducted by 3 researchers, with disagreements resolved by the second-round of reviews and discussions. The screening process is documented in the PRISMA 2020 flow diagram (Figure 1).



Note. Flow diagram adapted from the PRISMA 2020 statement (Page et al., 2021). Screening applied the four exclusion criteria reported in the text (publication date, peer-review status, educational level, and language); the source manuscript does not report a per-criterion breakdown of the 935 records excluded at this stage.

PRISMA 2020 Flow Diagram of Study Identification, Screening, and Inclusion

3.2. Bibliometric and Thematic Analysis

VOSviewer (version 1.6.20) was used for keyword co-occurrence analysis (minimum occurrence threshold: five) and co-citation analysis with cited references as the unit of analysis (minimum co-citation threshold: three). Cluster solutions were generated with VOSviewer's default association strength normalization. The quantitative clusters were then subjected to qualitative thematic synthesis: the top 5 most-cited and top 5 most-co-cited works in each cluster were read in full and coded for research design, population, findings, and claims structure.

The corpus analyzed here is the same corpus of 312 articles/literature assembled for a companion framework study (Author, 2026, manuscript submitted for publication). That study reports the cluster solution summarily as the empirical basis for a governance matrix; the present paper reports the full synthesis, including per cluster evidence assessment and gap analysis, which the companion paper does not contain. This reuse of the same corpus of 312 articles/literature is disclosed in the submission cover letter.

4. Results:

4.1. Corpus Structure and Temporal Evolution

The keyword co-occurrence analysis identified 89 keywords meeting the threshold, organized into six clusters. The highest total link strength (TLS) values belonged to "artificial intelligence" (TLS = 847), "academic integrity" (TLS = 612), "higher education" (TLS = 589), "AI literacy" (TLS = 534), and "accountability" (TLS = 498). That two of the five most central terms concern responsibility and trust, rather than technology or pedagogy, is itself a finding: the field's center of gravity is normative. The six clusters and their most central keywords are summarized in Table 1.

Table 1.

Six Keyword Co-occurrence Clusters (89 keywords meeting the threshold)

Keyword cluster	Keywords (n)	Most central keywords (by total link strength)
AI technologies and tools	13	artificial intelligence (847), generative AI, large language models, ChatGPT, agentic AI
Transparency, explainability, and AI literacy	20	higher education (589), AI literacy (534), transparency, explainability, disclosure
Academic integrity and assessment	17	academic integrity (612), plagiarism detection, academic dishonesty, assessment design, AI detection

Accountability and institutional governance	14	accountability (498), institutional policy, AI governance, responsibility, regulation
Human oversight and value alignment	16	human oversight, value alignment, epistemic integrity, autonomy, human-in-the-loop
Equity, access, and algorithmic fairness	9	equity, algorithmic fairness, digital divide, minority-serving institutions, access

Co-citation analysis (cited references as the unit of analysis) produced five clusters, summarized in Table 2: transparency and explainability ($n = 89$); distributed accountability and liability ($n = 74$); human oversight and controllability ($n = 61$); value alignment and epistemic integrity ($n = 58$); and equity, access, and algorithmic fairness ($n = 30$). Publication dates within clusters reveal a clear temporal structure. Work published 2019 to 2022 concentrates on predictive and reactive systems, plagiarism detection, learning analytics ethics, and AI literacy definition; from 2023 onward the corpus pivots sharply, with the steepest growth in papers organized around agentic properties.

The equity cluster is the smallest but fastest growing, with the steepest year over year citation trajectory in the corpus. The keyword and co-citation solutions are related but not identical: the six keyword clusters partition the field by topic vocabulary, while the five co-citation clusters partition it by shared intellectual ancestry. Their alignment on integrity, accountability, and literacy themes, and their divergence at the margins, where keyword clusters separate tool specific discussion that co-citation analysis merges, indicates a field whose terminology is still ahead of its theoretical consolidation.

Table 2.

Five Co-Citation Clusters in the Corpus ($N = 312$)

Cluster	n	Anchor Works (Most Co-cited)	Dominant Concern	Principal Gap
Transparency and explainability	89	Gabriel et al. (2024); Kasirzadeh & Gabriel (2025); Yu & Yu (2023)	Interrogability of AI reasoning in academic work	Principles rarely operationalized
Distributed accountability and liability	74	Mukherjee & Chang (2025); Kapoor et al. (2025); Chan (2023)	Who answers when agentic AI causes academic harm	Almost no empirical accountability studies

Human oversight and controllability	61	Gabriel et al. (2024); Kasirzadeh & Gabriel (2025)	Designed (versus assumed) human control	Student rights largely untheorized
Value alignment and epistemic integrity	58	Durand-Folco & Martineau (2023); Bean (2011); Furze (2024)	Epistemic development under AI assistance	Long term learning outcomes unmeasured
Equity, access, and algorithmic fairness	30	UNESCO (2021); Arum et al. (2025); IDRC (2024)	Differential access, support, and bias exposure	Smallest cluster; MSIs and Global South missing

Note. n = documents per co-citation cluster. MSIs = minority-serving institutions; IDRC = Inclusive Design Research Centre.

4.2. Cluster 1: Transparency and Explainability

The largest cluster is anchored by the theoretical program of Gabriel et al. (2024) and Kasirzadeh and Gabriel (2025) and, on the education side, by Yu and Yu's (2023) earlier bibliometric mapping of AI ethics in education. Its organizing problem is interrogability: whether the humans who must evaluate AI assisted academic work, instructors grading it and students defending it, can access the reasoning that produced it. The literature converges on three points. It agrees that visibility of agent behavior and interpretability of agent reasoning are distinct requirements, frequently conflated in institutional policy. It agrees that the burden of explanation should rise with the system's autonomy, since more autonomous systems perform more of the cognitive work whose provenance matters. And it agrees that in practice neither requirement is met: universities license and permit tools whose reasoning neither party to the assessment relationship can inspect (Hibbert et al., 2024).

Where the cluster is weakest is in operationalization and evidence. Most contributions state transparency as a principle rather than a testable requirement, a pattern Yu and Yu (2023) already observed and which persists in the literature that followed the agentic turn. Empirical work is dominated by AI literacy studies, competency definitions descending from Long and Magerko (2020) and Ng et al. (2021), assessment frameworks (Chee et al., 2025), and gray literature institutional guides (Digital Education Council, 2025; EDUCAUSE, 2024; European Commission & OECD, 2025). These document what students and staff should understand about AI systems, but almost no studies test whether transparency mechanisms, disclosure logs, provenance records, reasoning traces, actually change instructor judgment or student learning. Methodologically, the cluster is dominated by conceptual analysis, framework proposals, and survey research; experimental and design-based studies

are rare, and the few competency instruments that exist (Chee et al., 2025) have been validated for reactive tools rather than agents. The cluster thus exhibits a characteristic shape: theoretically sophisticated, prescriptively rich, empirically thin.

4.3. Cluster 2: Distributed Accountability and Liability

The second cluster joins two literatures that citation patterns show becoming one: a philosophical literature on responsibility for autonomous systems and an applied literature on academic integrity. From the first side, Mukherjee and Chang (2025) supply the cluster's most borrowed concept, the diffusion of responsibility across developers, deployers, and users when autonomous systems cause harm, and Kapoor et al. (2025) supply its most cited design argument, that agentic systems should be built to serve user rather than platform interests. From the second side, the empirical record is comparatively strong: systematic reviews document both the efficiency benefits and the dishonesty risks of generative AI (Bittle & El-Gayar, 2025), studies trace integrity failures to assessment design rather than student character (Cotton et al., 2023), and demonstrations of detector unreliability, including false positives on canonical historical texts, have effectively closed the debate on detection as a governance strategy (Edwards, 2023).

The cluster's live disagreement concerns where integrity governance should reside. One position treats integrity as a rules problem: clearer syllabus taxonomies of permitted, restricted, and prohibited AI use (Chan, 2023) and graduated scales of AI involvement (Furze, 2024). A second treats it as a development problem: what matters is not compliance but whether students' epistemic agency grows or atrophies under AI assistance (Ardito, 2025; Durand-Folco & Martineau, 2023). Citation practice suggests the field is migrating from the first position to the second, consistent with professional bodies' shift from prohibition to disclosure norms (American Psychological Association, 2023). What neither position yet possesses is evidence: the cluster contains almost no studies that follow an accountability arrangement through an actual integrity incident, and none that test whether taxonomies, disclosure memos, or attestation regimes change behavior. The cluster is also conspicuously silent on liability in the legal sense. Although its vocabulary is juridical, responsibility, liability, accountability, contributions from legal scholarship are nearly absent from the co-citation network, so questions that will eventually be settled in contracts and courts, such as a vendor's obligations when its agent fabricates sources in a graded submission, are being theorized without the discipline best equipped to answer them.

4.4. Cluster 3: Human Oversight and Controllability

The third cluster is the most theoretically consolidated and the most empirically deserted. Its consensus claim, articulated by Gabriel et al. (2024) and formalized by Kasirzadeh and Gabriel (2025), is that

human control over AI systems is a designed property, not a default one, and that governance should specify autonomy thresholds above which human in the loop review is mandatory. Education scholarship in this cluster imports the distinction between nominal control (a human formally initiates and approves) and substantive control (a human can competently interrupt, redirect, and reject), and observes that student initiated agentic work often satisfies only the former.

Three features of this cluster stand out in the synthesis. First, nearly all of its work addressing education is conceptual or policy analytic; oversight mechanisms such as review checkpoints, permission scoping, and override rights are proposed frequently and evaluated never. Second, the oversight relation studied runs almost exclusively from institution to student; the reciprocal relation, students' rights against AI systems imposed on them, in grading, feedback, and advising, appears only at the margins, chiefly via Kapoor et al.'s (2025) agent advocate argument, and remains untheorized in terms specific to education. Third, the cluster has begun to attract policy attention faster than research attention, with governance proposals surfacing in legislative and regulatory venues (Executive Order No. 14277, 2025; Federation of American Scientists, 2026) that cite the same thin conceptual base. The risk this creates, policy consolidating around unevaluated mechanisms, is discussed in Section 5.

4.5. Cluster 4: Value Alignment and Epistemic Integrity

The fourth cluster is the field's pedagogical conscience. Its anchor works are older than the others', because its central concept predates AI: Bean's (2011) argument that intellectual development requires productive struggle, imported into the AI debate to ask what happens when an agent absorbs the struggle on the student's behalf. Durand-Folco and Martineau (2023) give the cluster its political economy, warning of credentials accumulating without the capacities they certify, and the practitioner wing supplies its instruments: staged models of institutional adaptation (Maloney, 2023), graduated AI involvement scales (Furze, 2024), and ethics integrated course design frameworks (Online Learning Consortium, 2025).

The cluster's convergent finding, consistent across otherwise disparate work, is that assessment design, not policy language, is the operative variable: tasks eliciting generic responses invite substitution, while tasks demanding localized knowledge, iterative process evidence, or oral defense make AI use visible and pedagogically tractable (Cotton et al., 2023). Faculty development research reaches the parallel conclusion that practice-based programs outperform policy dissemination (Alier et al., 2024; Monzon & Hays, 2025; UNESCO, 2024), and institutional case studies confirm that policy without capacity produces confusion rather than compliance (Azevedo et al., 2025; Wu et al., 2024). The gap is longitudinal: no study in the corpus measures whether redesigned assessment actually protects learning outcomes over semesters or degrees, so the cluster's central causal claim, that

alignment oriented design preserves epistemic development where prohibition does not, rests on theory and short-term indicators rather than direct evidence. The mechanisms the cluster proposes are nonetheless the field's most concrete: process portfolios, annotated revision of AI output, reflective disclosure memos, and oral defense all have clear operational definitions and could be evaluated with standard educational research designs, which makes this cluster the natural starting point for the implementation studies the field lacks.

4.6. Cluster 5: Equity, Access, and Algorithmic Fairness

The smallest cluster carries the largest normative weight and the steepest growth curve. Its empirical anchor is Arum et al.'s (2025) documentation of stratified adoption: students at less selective institutions receive less institutional support for AI use even as they face equal or greater exposure to its risks. Its normative anchor is UNESCO's (2021) recommendation on AI ethics, and its design anchor is the Inclusive Design Research Centre's (2024) triad of access, support, and bias audit. The cluster's distinctive analytical move is to treat AI harms as compounding rather than additive: access gaps produce competency gaps, which amplify exposure to algorithmic bias in the AI assisted grading and adaptive systems most common at under resourced institutions.

Two silences define this cluster more than its contents. Community colleges, historically Black colleges and universities, Hispanic-serving institutions, and tribal colleges, precisely the institutions where the cluster's compounding logic predicts the greatest harm, are nearly absent as research sites rather than as objects of concern. And the Global South appears almost exclusively through intergovernmental gray literature rather than empirical study. A literature whose fastest growing theme is inequity, studied overwhelmingly at well-resourced institutions in the Global North, is a literature measuring the problem where it is smallest.

5. Gaps and Research Agenda

Read across rather than within clusters, the synthesis yields six structural gaps. The gaps are not independent: the measurement gap blocks the implementation studies that would close the evidence deficit, the population blind spots guarantee that whatever evidence does accumulate will generalize poorly, and disciplinary insulation keeps the expertise needed for accountability questions outside the field. Closing them in isolation is therefore unlikely to work; the agenda below is ordered so that measurement and implementation work enable the rest. Table 3 pairs each with the research designs most likely to close it.

First, an implementation deficit: conceptual, prescriptive, and policy analytic work outnumbers empirical implementation study in every cluster; proposed mechanisms (disclosure memos, oversight checkpoints, bias audits) circulate widely without ever being evaluated in a live course or institution.

Second, a measurement gap: the field possesses no validated instruments for its own core constructs, responsible use, epistemic integrity under AI assistance, substantive oversight capacity, leaving studies to rely on self-reported measures and ad hoc rubrics.

Third, population blind spots: minority-serving institutions, community colleges, and Global South universities are objects of equity argument but rarely sites of data collection.

Fourth, an accountability asymmetry: student obligations are elaborately specified across the corpus while institutional and developer obligations remain gestural, an inversion of where power over agentic systems lies.

Fifth, temporal fragility: a large share of the corpus's empirical base predates agentic capabilities, and no study tests whether findings from research on reactive tools transfer to systems that plan and act; the field may be governing tomorrow's systems with evidence about yesterday's.

Sixth, disciplinary insulation: co-citation patterns show education research and technical AI governance scholarship citing largely disjoint literatures, meeting only through a handful of boundary works (Gabriel et al., 2024; Kasirzadeh & Gabriel, 2025), which slows the translation of technical governance advances into educational practice and of educational evidence into system design.

Table 3.

Gap by Gap Research Agenda

Gap	Exemplar research questions	Priority designs
Implementation deficit	Do disclosure memos or oversight checkpoints change instructor and student behavior?	Field experiments; design-based implementation research in live courses
Measurement gap	What observable indicators validly distinguish responsible from substitutive AI use?	Instrument development and validation; measurement invariance studies
Population blind spots	How do agentic AI governance needs differ at MSIs, community colleges, and Global South institutions?	Multi-site comparative case studies; partnerships with under resourced institutions
Accountability asymmetry	What developer and institutional obligations are enforceable, and how?	Policy analysis with legal scholarship; procurement contract studies

Temporal fragility	Do reactive tool findings replicate with agentic systems?	Systematic replications varying system autonomy
Disciplinary insulation	What educational evidence should inform agent design, and vice versa?	Cross venue collaborations; boundary spanning special issues

Note. MSIs = minority-serving institutions.

6. Discussion:

Three implications follow from the map. For researchers, the synthesis reorders the field's incentives: the marginal value of another conceptual framework or policy commentary is now low in every cluster, while the marginal value of implementation studies, validated instruments, and research at underrepresented institutions is high. The comparison with adjacent syntheses sharpens the point: integrity focused reviews (Bittle & El-Gayar, 2025) and mappings that precede the agentic turn (Yu & Yu, 2023) each found their literatures long on concern and short on intervention evidence, and the present synthesis shows that the agentic turn has widened rather than narrowed that ratio, because theory has moved faster than fieldwork.

For editors and reviewers, the temporal fragility gap suggests a concrete practice: requiring authors to specify the agentic profile of the systems they study, at minimum the autonomy and generality of the tools involved, so that future syntheses can distinguish evidence about reactive tools from evidence about agents. Much of the current corpus is ambiguous on exactly this point, which is why the transfer question cannot presently be answered.

For funders and institutional leaders, the population blind spots and the accountability asymmetry are the actionable findings. Both reflect resource allocation rather than intellectual difficulty: studying implementation at a community college costs more relational investment than theorizing at a research university, and specifying developer obligations requires legal and procurement expertise that education faculties rarely hold. Targeted funding and interdisciplinary teams are the plausible correctives; the research agenda in Table 3 is designed to be fundable in precisely that form.

For practitioners, finally, the map is usable now even where the evidence is thin, provided it is used honestly. Institutions selecting among governance mechanisms should prefer those the literature defines operationally (the assessment design instruments of the value alignment cluster) over those it defines only aspirationally (transparency principles without logging or provenance requirements) and should treat their own implementations as evaluable pilots rather than settled policy, since they will in effect be generating the evidence the research base is missing.

The synthesis also clarifies what should not be concluded. The dominance of normative over empirical work is not evidence that the field is unserious; it is the ordinary shape of a literature responding to a fast technological shock, in which conceptual triage precedes evaluation. The argument here is that the triage phase has done its work. The categories are stable, five clusters with clear anchors and boundaries, and the field's next phase should be evaluative.

7. Policy and Societal Implications

The societal stakes of this synthesis lie in what universities certify. Degrees function as public signals of capability; if agentic AI erodes the link between credential and competence faster than governance research can respond, the cost falls not only on institutions but on employers, professions, and the publics they serve. This synthesis shows that the research base underpinning institutional AI governance is thinnest exactly where societal exposure is greatest: at under resourced institutions serving the most vulnerable student populations, and at the level of developer and institutional obligation where power over agentic systems is concentrated. Policymakers drafting rules for AI in education, a process already underway in federal directives and legislative proposals, are therefore building on evidence about yesterday's tools, gathered at unrepresentative institutions, with student conduct specified in excessive detail and institutional conduct left thin.

The practical implications are threefold: regulatory frameworks should mandate transparency about the agentic profile of educational AI systems so that evidence and rules can be matched to actual capabilities; public research funding should be directed toward implementation and measurement studies at minority-serving and open access institutions; and procurement policy should be recognized as a governance instrument, since contract terms between universities and AI developers are currently an important and immediately actionable mechanism of developer accountability for universities. Without these corrections, AI governance in higher education risks consolidating around plausible but unevaluated mechanisms.

8. Conclusion:

This synthesis mapped 312 peer reviewed publications on the ethics and governance of AI in higher education onto five stable thematic clusters, assessed the evidence within each, and identified six structural gaps that jointly define the field's next research phase. The picture that emerges is of a literature that has completed its conceptual work and not yet begun its empirical work: rich in frameworks, principles, and warnings; poor in implementation evidence, validated measures, and representative research sites. As AI systems in universities become more autonomous and more general, the cost of that imbalance compounds, because governance decisions are being made now,

at every institutional level, on the strength of the conceptual literature alone. The agenda proposed here, evaluative, measured, and deliberately aimed at the institutions and actors the field has overlooked, is offered as the map for that work.

9. Limitations:

This synthesis is limited to English-language, peer-reviewed records indexed in Web of Science and Scopus. Database coverage bias is therefore a constraint: preprints, policy gray literature (except where cited contextually), and scholarship not published in English are excluded—a material constraint given the Global South gap the synthesis itself identifies. Search-term sensitivity is an additional limitation; alternative keyword choices might have retrieved a somewhat different corpus. Citation-indexing lag means the newest scholarship is underrepresented: co-citation analysis privileges older, well-cited works and gives less weight to recent publications, so the 2025–2026 literature is represented conservatively. Bibliographic metadata errors in the source databases may have introduced noise into the corpus. The cluster solutions depend on VOSviewer parameter choices (occurrence and co-citation thresholds); alternative thresholds could yield somewhat different partitions. Cluster labeling involves interpretive judgment, and although anchored in quantitative co-citation structure, alternative labels are defensible. Finally, the corpus was assembled in March 2026; in a field growing this quickly, the map ages fast and should be rerun periodically. The corpus is shared with a companion framework study (Author, 2026, manuscript submitted for publication), as disclosed in Section 3.2.

Ethics Approval and Consent:

Not applicable. This study synthesizes published literature and involved no human or animal participants.

Data Availability:

The search strings, screening log, and the full corpus of 312 records with cluster assignments are available from the corresponding author upon reasonable request.

Code Availability:

Not applicable. Analyses used VOSviewer 1.6.20 with parameter settings reported in Section 3.2; no custom code was written.

Competing Interests:

The author(s) declare no competing interests.

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Use of Generative AI Tools:

Generative AI tools (Gemini Pro and ChatGPT) were used to assist with copy editing, formatting, and reference verification during the preparation of this manuscript. All searches, screening decisions, coding, analysis, interpretations, and conclusions are the authors' own, and the author verified and take full responsibility for all content.

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The Reality of Employing Modern Educational Technologies to Develop some Mathematical Concepts in Early Childhood from the Perspectives of Early Childhood Teachers in Makkah Al-Mukarramah

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Abstract:

This study aimed to examine early childhood teachers' self-reported use of modern educational technologies in developing certain mathematical concepts. A descriptive survey design was employed, and a questionnaire was administered to 234 early childhood teachers. The findings revealed a high level of self-reported use of modern educational technologies in developing mathematical concepts ($M = 3.95$, $SD = 1.03$). Teachers also reported a high level of perceived importance of using these technologies to support children's mathematical concept development ($M = 4.07$, $SD = 0.99$). In addition, perceived barriers to using modern educational technologies were rated as high ($M = 3.94$, $SD = 1.08$), indicating challenges that may limit their effective integration into teaching practices. The study recommends providing workshops and training programs to enhance teachers' effective use of modern educational technologies, encouraging their integration into classroom practices to promote children's engagement and motivation to learn, using the Early Childhood Developmental Learning Standards Guide as a reference for developing mathematical concepts, and creating supportive learning environments by providing the materials, and technological resources for effective implementation.

Keywords: modern educational technologies, mathematical concepts, female early childhood teachers.

1. Introduction:

In light of the rapid technological developments witnessed in the current world, technological innovations have become prevalent in all areas of life, especially in the educational field, to address many problems and challenges, making it necessary to use technological innovations in the field of education. The world has developed technologically at a rapid pace, which has led to the necessity of using technological innovations in the educational process, due to its direct impact on the method of teaching and learning, as it contributes to improving the educational process and making it more effective and exciting, and has a great impact on the learner's motivation and development. (Al-Matrafi & Al-Suhaim, 2025).

The rapid emergence of new educational technologies is consistent with ongoing advances in information and communication technology, and the associated progress in communications that humanity has never known before, has led to the reformulation of educational strategies and the orientation in line with the current era by employing technological innovations. Hence came the importance of preparing teachers who are able to employ these technological innovations effectively during the educational process (Abu Hamda, 2022).

Mathematics is considered one of the indispensable subjects in all stages of education. One of the most important features of modern mathematics is that it is not considered merely traditional operations or skills, but rather represents the foundation upon which it is built. The basic building blocks of this structure are the establishment of mathematical concepts in the kindergarten child, as the foundations and skills of mathematics depend greatly on concepts in their establishment and acquisition until they become smoother and more understandable (Salem, 2022).

Some studies have emphasized the enhancement of learning through the integration of technologies in learning mathematical concepts, such as the study (Serin, 2023), which confirmed that technology enhances the learning process, thinking skills, achievement, motivation and efficiency of learners, makes learning more interesting, creates a real educational environment for learning mathematics, and facilitates linking concepts to the real world and helps learners to visualize and understand better.

Accordingly, several studies were conducted, such as the Qarqash study (2019), the Jamil study (2020), and the Maghazi study (2023), which emphasized the development of mathematical concepts due to their importance, as they make them feel confident in themselves and their ability to achieve, express themselves, and acquire concepts and skills.

Early childhood is the first stage of building an individual's life, as it is a stage in which the traits of a person's personality are developed. Learning in the early years of a child's life forms the basis upon

which learning in the coming stages is based. Therefore, building mathematical concepts at this stage represents the main pillar and the basis upon which the child relies in the different stages of education (Muhammad, 2019).

1.1. Study problem:

In light of the rapid developments in the field of educational technologies, many educational technology innovations have emerged that can be employed in educational situations, allowing for diversification of content presentation methods, providing interactive activities, and providing opportunities for practice and feedback. Some relevant scientific conferences and forums have emphasized the importance of moving towards employing educational technologies and innovations in the educational process; As part of the Fourth International Conference on the Future of Digital Education in the Arab World (2023), which recommended the need for educational systems to pay attention to educational and technological technologies, and to create high-quality projects to bring about the digital transformation required to achieve development and progress, and to work to create a rich educational environment that supports the learning process, by providing the necessary tools and devices, and using new educational technologies, The Third International Conference of the Faculty of Early Childhood Education - Mansoura University (2021, May), which recommended in the closing session of the conference the necessity of working to develop the philosophy, goals and visions of educational programs directed at the Arab child and the extent to which they keep pace with light of digital transformation, while presenting a future vision for the training of the kindergarten child and teacher in light of technical and technological developments As well as discussing the reality of institutions and organizations responsible for raising children and developing future visions to bring about the required boom in the field of child care and upbringing in light of the concept of digital transformation. These recommendations are an indication of the growing interest in employing technological innovations in education. However, simply recommending their use does not clarify the reality of their actual use in educational practices, nor does it indicate the extent of their use in various educational fields.

By reviewing previous studies, it becomes clear that a number of studies are interested in employing new educational technologies, as Al-Shammari's study (2023) emphasized the necessity of supporting the activities provided to primary grades and kindergartens with technologies because of their effectiveness in acquiring concepts in an easy, fun and attractive way, because of their effectiveness in acquiring concepts in an easy, fun and attractive way, Al-Ghamdi's study (2022) presented a proposal to study the effectiveness of digital education innovations in achieving mathematics learning goals in kindergarten. These studies reveal the importance of employing technical innovations, but their results

also indicate that benefiting from these innovations is linked to the extent of their appropriate employment in educational practices, and to the teacher's ability to choose the technology appropriate to the nature of the content and the characteristics of the learners.

Many studies, such as Nassar's (2021) study, have focused on the importance of developing mathematical concepts from the stage of entering the educational stage to help him develop the ability to think, increase the speed of intuition, and make the child more intelligent in light of this constantly evolving world. This is what was confirmed by the study of (Edelman 2017) found that preservice elementary teachers require further development in their ability to identify mathematical concepts in children's literature and to critically evaluate curricular materials and mathematical representations when planning and teaching mathematics lessons.

Considering the overall findings of previous studies, it is clear that they addressed the use of new educational technologies on the one hand, and the importance of developing mathematical concepts in early childhood children on the other hand. However, the relationship between these two aspects still needs further research, especially with regard to the reality of using new educational technologies in developing some mathematical concepts from the point of view of early childhood teachers, It is also not sufficiently clear the level of use of these innovations in educational practices related to mathematical concepts in the educational environment in the city of Makkah Al-Mukarramah. Hence, the scientific gap that the current study seeks to address is to reveal the reality of employing new educational technologies in developing some mathematical concepts from the point of view of early childhood teachers in Makkah Al-Mukarramah.

Accordingly, the current study aims to contribute to addressing this gap by providing a scientific description of the reality of employing new educational technologies in developing some mathematical concepts from the perspective of early childhood teachers in Makkah Al-Mukarramah, and revealing the level of employing this new technology.

1.2. Study Questions:

This study seeks to answer the following main question:

To what extent do early childhood teachers report using modern educational technologies to develop certain mathematical concepts?

The following sub-questions stem from this main question:

1. What is the current state of employing modern educational technologies in developing certain mathematical concepts from the perspective of early childhood teachers?
2. How do early childhood teachers perceive the importance of using modern educational technologies to develop certain mathematical concepts?

3. What barriers do early childhood teachers report to using modern educational technologies in developing certain mathematical concepts?

1.3. Study Objectives:

This study aimed to:

1. Identify the current state of employing modern educational technologies in developing certain mathematical concepts from the perspective of early childhood teachers.
2. Identify the importance of employing modern educational technologies in developing certain mathematical concepts from the perspective of early childhood teachers.
3. To identify the barriers reported by early childhood teachers to using modern educational technologies in developing certain mathematical concepts.

1.4. Significance of the Study:

1.4.1. Theoretical Contributions:

This study may contribute to enriching local and international libraries and research in the field of identifying how teachers utilize modern educational technologies to develop certain mathematical concepts in early childhood.

This study is unique (to the best of the researcher's knowledge) in addressing the reality of using modern educational technologies to develop certain mathematical concepts from the perspective of early childhood teachers.

1.2.1. Practical Significance

The results of this study may benefit education departments by encouraging teachers to utilize modern educational technologies to develop certain mathematical concepts in early childhood education, through providing these technologies and enhancing training programs.

The theoretical framework and recommendations of this study may also benefit early childhood teachers by highlighting the importance of employing modern educational technologies to develop certain mathematical concepts.

1.5. Study terminology:

Educational Technology Innovations:

Everything new or emerging in educational devices and materials, theories of their operation, and methods of designing, producing, and using them to support the education system, or any of its components, in order to raise the efficiency of educational systems and achieve quality standards for the inputs, processes, and outputs of those systems (Al-Subaie, 2020).

The researcher defines it as a set of modern technical materials and tools used to clarify and simplify concepts for the child in order to develop and increase the effectiveness of learning, whether synchronously or asynchronously.

Mathematical concepts:

A set of abstract symbols that can be classified in relation to one another (Al-Khadidi & Al-Abadi, 2024).

The researcher defines it as the mental image that a child forms based on the common characteristics of things that share the same shape, color, or quality. Examples of mathematical concepts include counting, classification, and geometric shapes.

Early Childhood:

This stage, spanning ages 3-8, is characterized by the laying of the foundations for physical, social, emotional, and intellectual development. These developments occur concurrently, and each stage builds upon the child's achievements in the preceding stage (Ministry of Education, 2021).

The researcher defines it as the stage when a child is between 5 and 6 years old and possesses the ability to understand and comprehend mathematical concepts.

1.6. Study Delimitations:

- ***Spatial Delimitations:*** Some early childhood schools in Makkah.
- ***Temporal Delimitations:*** Second semester of the year 1447 AH.
- ***Mankind Delimitations:*** Early childhood teachers.
- ***Thematic Delimitations:*** Identifying The reality of employing modern educational technologies in Developing some Mathematical Concepts.

2. Literature Review and Theoretical Framework:

This chapter outlines the theoretical and conceptual framework of the research, dividing it into two main sections. The first section addresses the Innovations in educational technology, including its definition, its characteristics, importance, and supporting theories, with a focus on using innovative educational technologies in early childhood.

It then moves to Its Definition Mathematical concepts, importance, how mathematical concepts are formed in early childhood, and the teacher's role in teaching mathematical concepts.

2.1. Modern educational technologies:

Although educational technologies have existed for a long time, they have developed rapidly in recent times, and their use in the educational field has become very necessary for better and broader learning,

as they have led to a transformation and development in various fields. Al-Saidaoui (1976) first defined them as the structures, formulas, methods and educational tools that enable us to achieve the learning of the largest possible number of individuals in a better, faster and more effective way and at a lower cost.

2.1.1. Definition of Modern Educational Technologies:

Tawfiq et al. (2022) defined it as several models, systems, methods and modern interactive educational technologies that have benefited educational technologies, such as: information and communication technologies that develop and continuously update the educational process to achieve its goals efficiently and effectively.

Salim et al. (2024) defined it as everything new and innovative (electronic devices and tools, teaching strategies, learning applications and environments, assessment tools, and technological solutions) that contributes to raising the level of the learning process and increasing its effectiveness, in order to achieve the goals of education.

2.1.2. Characteristics of modern educational technologies:

Some of the characteristics of modern educational technologies include:

- Interactivity: The ability to interact with, exchange, and receive information and experiences with others regardless of geographical distance.
- Diversity: The variety of teaching and assessment methods and tools, and the multiplicity of learning environments and information sources.
- Learner empowerment: Facilitating the learning process for the learner with a high level of efficiency and effectiveness in minimal time and effort.
- Flexibility: Access to information from various countries around the world. Hakami (2020).

In addition to the characteristics, are also included:

- Motivation: Modern educational technologies help increase learners' motivation to learn.
- Integration: It contains several comprehensive and integrated educational materials.
- Continuity: Educational technologies are reviewed and updated regularly to keep pace with current trends.
- Individualization: This allows learners the opportunity to learn independently according to their own abilities and pace.

2.1.3. Theoretical Foundations of Educational Technology Integration:

Modern educational technologies integrate various learning theories and are not limited to a single learning theory. Below are some of the theories that support modern educational technologies:

2.1.3.1. Constructivist Theory:

According to Crawford and Jenkins (2018), constructivist theory views learners as actively constructing knowledge through their personal experiences.

Constructivist theory supports the use of new educational technologies by encouraging children to build their own knowledge and encouraging children to interact and participate actively within the educational process.

2.1.3.2. Behaviorist Learning Theory:

Hanachi (2025) believes that incorporating technology into education requires familiarity with the learning theories underlying highly effective teaching practices. Thus, behavioral theory provides an important perspective, and reinforcement plays a necessary role in education. Therefore, this concept can be integrated into technology using features such as virtual rewards, which motivate learners and contribute to enhancing learning.

This theory results in effective educational outcomes by creating an active learning environment for the child, starting from the occurrence of stimuli using the latest educational technologies, gradually learning from easy to difficult in the educational content and choosing appropriate technologies.

2.1.3.3. Learning Styles Theory:

Al-Azzawi (2017) indicated that the theory of learning styles has an impact on the educational process, so that teachers must prepare educational content related to the different learning styles of learners through their experience and thinking, and they must provide diverse elements to the educational environment such as sound, visual media, movement, and experience.

The latest educational technologies support this theory because they provide auditory, visual, and sensory forms and patterns. The researcher adds that the theory of learning styles contributes to the use of diverse technological innovations, including images and sensory forms.

2.1.4. *Integration of Modern Educational Technologies in Early Childhood Education:*

Al-Naqeeb (2024) explained the philosophy of using educational technology innovations in light of the early childhood education system in the following points:

- Technological competence is considered one of the requirements for lifelong learning in the current era.
- Children today need the knowledge, skills, and attitudes to cope with the rapid pace of change and the growing knowledge base.

- When used appropriately, technological innovations enhance child-centered learning and the teacher's role as a facilitator of learning.
- Technology contributes to expanding the scope of children's learning, becoming a powerful tool for transforming education and tailoring experiences to meet the needs of all children, making learning more effective and engaging.
- Short videos or educational apps.

2.1.5. Educational Benefits of Modern Technologies:

Studies and research in the field of educational technology have confirmed that employing educational technologies increases the effectiveness of the educational process and plays a significant role in the following:

- Improving student learning outcomes.
- Enhancing classroom participation.
- Making the educational process more relevant to reality, continuous and applicable (Al-Taf, 2019).

The researcher adds to the importance of educational technology innovations that:

- Developing the understanding of concepts: It develops concepts from all directions, as it helps in managing time and reducing the burden, and thus the educational process progresses more quickly, while achieving the desired results.
- Increased enjoyment of understanding concepts: With the development of educational innovations, teaching methods have diversified, making learning more enjoyable and reducing the sense of boredom and repetition associated with traditional learning, thus enhancing learners' interaction towards positive participation and making learning more exciting and effective.
- Enhancing the Teacher's Role: Learning technologies allow teachers to employ a variety of methods to tailor instruction to learners' needs, and help them identify and address learning gaps.
- Facilitating Comprehension: Learning technologies enable learners to grasp content by engaging their senses. Content is presented through multiple media (visual, auditory, textual, and interactive) simultaneously.

2.2. Mathematical Concepts in Early Childhood:

Mathematical concepts have become one of the essential branches of science upon which every child depends to make decisions related to his daily life, regardless of his cultural environment. Therefore, they have gained an essential place in various educational stages and in various curricula, as they enhance and contribute to the development of thinking skills, which contributes to increasing children's intelligence. Mathematical concepts are also considered to be of great importance in an ever-advancing

era (Nassar et al., 2021), and they have become essential, as emphasized by the national curriculum (Ministry of Education, 2021).

2.2.1. Definition of Mathematical Concepts:

Al-Qarni (2023) defined it as a set of interconnected concepts from which a student's mental ideas are generated, resulting from the generalization of characteristics and features derived from similar applications within that concept. It is indicated by a symbol or name.

Anggraini (2023) defined it as an abstract conceptual framework that enables individuals to classify things and concepts and clarify whether they are examples of the abstract idea or not.

2.2.2. Importance of Mathematical Concepts in Early Childhood:

Saeed et al. (2020) stated that learning mathematical concepts is of great importance because it leads to:

- Reducing the need for reteaching, as the concepts that the child acquires are applied and used repeatedly in many educational situations without the need to reteach them.
- It helps reduce learning difficulties when a child transitions from one educational stage to another.
- It helps structure different types of information.
- It helps teachers and learners understand the nature of science.

The importance of mathematical concepts to the researcher is evident from the above, as they are the first pillar for building basic knowledge, and they help the child to remember what is learned and to understand deeply. The laws are not understood except after grasping the mathematical concepts.

2.2.3 Mathematical Concept Development in Early Childhood:

Bruner's concept formation occurs in three main stages, the most important of which are:

- The practical stage: This is the sensory-perceptual stage where the learner participates directly, and action is the natural and fundamental way to understand the environment. In this stage, the child connects concepts to actions that represent the concept.
- The figurative stage: Information is conveyed and represented to the child through images without the need for direct physical representation.
- The symbolic stage: In this stage, the child reaches the stage of abstraction and uses symbols to replace physical actions. (Bou Bilal & Ben Dhib, 2022).

2.2.4. Classification of mathematical concepts:

There are multiple and different classifications of mathematical concepts, as mentioned by Al-Na'ma (2025), including the following:

- Sensory and Abstract Concepts: Sensory concepts belong to a set of physical components that can be observed and measured, while abstract concepts are intangible and belong to a set of abstract things that cannot be observed or measured. The majority of mathematical concepts are abstract.
- Single and General Concepts: Single concepts are those that belong to single-unit sets, meaning they consist of only one component, such as the concepts of odd and even numbers.
- Procedural concepts: These are concepts that focus on methods of operation, such as adding, subtracting, dividing, and multiplying numbers.
- Associative concepts: These are concepts that involve the connection between two or more concepts, such as density.
- Definable concepts: These are concepts that can be defined by a statement that specifies the concept.

2.2.5. Teachers' Role in Supporting Mathematical Concept Learning:

The role of the teacher in facilitating the understanding of mathematical concepts goes beyond simply presenting information in ready-made forms and answering questions. Al-Salahi (2020) mentioned this as follows:

- Analyze the concepts being explained to identify their core meanings.
- Verify that students possess the core concepts related to the concepts being explained, and explore alternative conceptions of the concept among students through interactive activities.
- Guiding students to a state of cognitive dissonance through exploratory activities.
- Employing diverse strategies for explaining concepts that emphasize the student's active role; these strategies may be inductive or deductive.
- Creating a learning environment rich in tangible materials that supports the exploratory nature of geometric concepts.

2.3. Review of Previous Research:

Al-Maliki and Al-Abadi study (2023): This study aims to identify the attitudes of kindergarten teachers in Makkah towards using educational technology in teaching children, and its relationship to certain influential variables (academic qualification and years of experience). The researcher employed a descriptive survey methodology, and the study sample consisted of 183 teachers. The results showed no statistically significant differences between the mean scores of the study sample's responses attributable to the variables of academic qualification and years of experience. In light of these findings, the study recommends that policymakers reconsider the development of kindergarten curricula to align with educational technology and the needs of the community, and that the necessary

guidelines for the optimal use and integration of technology in teaching be included in the teachers' handbook.

S. Al-Ghamdi's study (2022): The study aims to reveal the reality of the use of technological innovations from the point of view of the teachers of the Early Childhood Kindergarten and Primary School in Al-Baha and their attitudes towards them. The researcher followed the descriptive analytical method, and the study sample consisted of (30) teachers. The results concluded that the availability of technological innovations and their use was high in the Early Childhood Kindergarten and Primary School in Al-Baha, and that there are difficulties that hinder the use of technological innovations by the primary stage teachers in the school to a moderate degree.

Ali's study (2021): This study aimed to measure the effectiveness of a digital learning-based program in developing historical awareness among kindergarten children and to test its effect on enhancing their sense of belonging to the homeland. The researcher used the experimental method with two equivalent groups, and the study sample consisted of (60) children from the second level. The results showed a statistically significant difference at the 0.01 level between the average scores of the children of the experimental group in the pre- and post-measurements on the scale of belonging to the homeland among kindergarten children, in favor of the post-measurement, which indicates the positive effect of the program in enhancing belonging to the homeland among kindergarten children.

Al-Rashed's study (2018): This study aimed to identify kindergarten teachers' attitudes towards the use of digital learning and the degree to which they possess digital learning skills. The researcher followed the descriptive approach, and the study sample consisted of (120) teachers from kindergartens in different areas of Riyadh. The results showed that there are positive attitudes towards digital learning.

Al-Warfali's study (2023): The study aimed to reveal the effectiveness of educational packages in developing mathematical concepts among children with Down syndrome (capable of learning) in the kindergarten stage. The two researchers in the study adopted the experimental method, the design of two groups (experimental and control) and the pre-test-post test. The study sample consisted of (18) children who were divided into two homogeneous groups. The results showed that there were statistically significant differences between the scores of the experimental group in the pre-test and post-test on the mathematical concepts scale at a statistical significance of 0.01, in favor of the post-test, which indicates the effectiveness of the program used in the current study in developing mathematical concepts.

Mohammed's study (2023): which aimed to develop a proposal using metacognitive strategies in developing mathematics concepts in kindergarten children with curriculum 2.0. The researcher

followed the quasi-experimental approach with a single group, and the study sample consisted of (30) children from kindergartens. The results showed that there was a statistically significant difference between the mean scores of the children in the study sample in the pre- and post-applications of the picture mathematics concepts test (in its entirety) in favor of the post-test, which is attributed to the use of the metacognitive strategy. There were also statistically significant differences between the mean scores of the children in the study sample in the pre- and post-applications of the concept of (numbers and arithmetic operations) in favor of the post-test.

Ibn Mardah's study (2022): The study aimed to identify the effect of employing reading comprehension strategies in developing the word problem-solving skill for mathematical concepts among fourth-grade elementary school students in Jeddah. The researcher used the experimental research method with the design of two experimental and control groups. The study sample consisted of (67) fourth-grade elementary school students from elementary school (17) in Jeddah. The study sample was divided into two groups: experimental (35 students) and control (32 students). The results showed that there was a significant effect of reading comprehension strategies in developing word problem-solving skills for mathematical concepts among fourth-grade elementary school students.

Al-Otaibi's study (2022): The study aimed to identify the mathematical concepts that should be developed among primary school students, and to reveal the effect of using augmented reality technology in developing mathematical concepts in primary school in the city of Makkah Al-Mukarramah. The researcher used the quasi-experimental method, and the study sample consisted of Al-Asma'i Primary School in the city of Makkah Al-Mukarramah. The sample consisted of (79) students distributed into two groups, experimental group, and the control group, the results of the study showed that there were statistically significant differences at the level of ($0.05 > \alpha$) between the mean scores of the students of the experimental group in the pre- and post-applications of the mathematical concepts test, in all the concepts represented by the test (length, mass, capacity, the concept of the metric system) and the overall test, in the direction of the post-application with the higher arithmetic means, and that there was a high positive effect of using augmented reality technology in developing mathematical concepts among the students of the experimental group, in all the concepts represented by the test and the overall test.

3. Methods:

3.1. Study Design:

The descriptive survey method was used because it was suitable for the nature of the study and its objectives, as it aims to collect data about a specific phenomenon, describe it, and interpret it

(Hassan, 1982, p. 213), in order to identify the reality of employing new educational technologies in developing some mathematical concepts from the point of view of early childhood teachers.

3.2. Study Population and Sampling:

The study population consisted of all early childhood teachers in the city of Makkah Al-Mukarramah, numbering (631) teachers according to the statistics of the General Administration in Makkah Al-Mukarramah. The study sample was selected using simple random sampling from the population of early childhood teachers in Makkah Al-Mukarramah, and its size was (234) teachers. The sample size was determined using the (Steven K. Thompson) equation in proportion to the size of the study population. The questionnaire was distributed electronically to the members of the sample, and all questionnaires were returned complete and valid for statistical analysis, thus representing the actual study sample.

Table (1) shows a description of the characteristics of the study participants by calculating the frequencies and percentages of their responses to the first section of the questionnaire related to (years of experience, level of familiarity with technological innovations).

Table 1. Demographic and Professional Characteristics of the Study Participants

Years of experience	Number	Percentage %	Level of Knowledge	Number	Percentage %
Under 5 years	38	16.2	Beginner	24	10.3
5 to 10 years	73	31.2	Intermediate	132	56.4
Over 10 years	123	52.6	Advanced	78	33.3
Total	234	100	Total	234	100

Table (1) shows that the majority of the study sample had teaching experience (more than 10 years), with (123) teachers representing (52.6%), followed by teachers with (5-10) years of experience, with (73) teachers representing (31.2%), while the number of teachers with less than 5 years of experience was (38) teachers representing (16.2%)

It is also evident that the majority of the sample have an intermediate level of familiarity with technological innovations, with (132) female teachers representing (56.4%), while the number of female teachers with an advanced level of familiarity was (78) female teachers representing (33.3%), while the category of beginner level of familiarity came in last place, with (24) female teachers representing (10.3%)

Accordingly, the researcher believes that the diversity of characteristics of the sample members in terms of years of experience and level of familiarity with technological innovations may contribute to providing diverse viewpoints on the reality of employing educational technology innovations in developing some mathematical concepts among early childhood children, which enhances the comprehensiveness of the results and allows for a clearer perception of the reality of employing these innovations from the teachers' point of view.

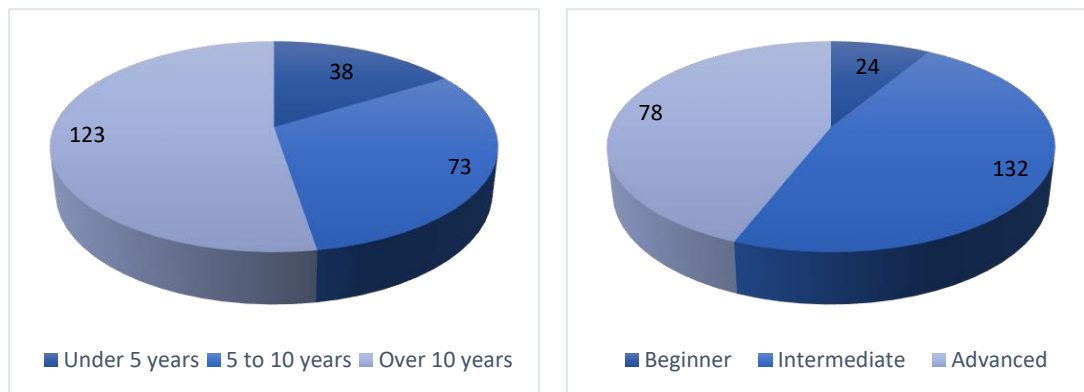


Figure 1. Distribution of Participants by Teaching Experience and Familiarity with Educational Technologies

3.3. Study instruments:

To achieve the study's objectives and answer its questions, the researcher prepared a questionnaire to gather the necessary information about the current state of employing modern educational technologies in developing certain mathematical concepts from the perspective of early childhood teachers. This was done after reviewing educational literature and previous studies and research related to modern educational technologies and their applications in the educational field, particularly those related to teaching mathematics and developing mathematical concepts in early childhood children.

The questionnaire was designed with careful consideration for clarity, accuracy, and suitability to the nature of the sample and the subject of the study, ensuring the collection of data necessary to achieve the study's objectives and answer its questions.

The initial version of the questionnaire consisted of two parts, as follows:

Part One: This section includes basic data on the study sample, aiming to identify their demographic and professional characteristics, including years of experience and level of familiarity with modern technologies.

Part Two: This section contains the questionnaire's sections, which measure the actual use of modern educational technologies in developing certain mathematical concepts among early childhood children. These sections were defined and their statements formulated based on educational literature

and previous studies and research related to the study topic. This section includes (20) statements distributed across three main sections as follows:

- The first axis: The degree to which modern educational technologies are employed in developing certain mathematical concepts from the perspective of early childhood teachers in Makkah Al-Mukarramah, comprising (7) statements.
- The second axis: The importance of employing modern educational technologies in developing certain mathematical concepts from the perspective of early childhood teachers in Makkah Al-Mukarramah, comprising (7) statements.
- The third axis: Obstacles to employing modern educational technologies in developing certain mathematical concepts from the perspective of early childhood teachers in Makkah Al-Mukarramah, comprising (6) statements.

Thus, the questionnaire in its initial form included (20) statements, and Participants' responses were measured using a five-point Likert scale, as shown in Table (2).

Table 2. Five-Point Likert Response Scale

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	4	3	2	1

Mean scores for the questionnaire items and their respective dimensions were interpreted according to predefined response-level categories based on the five-point Likert scale.

This was done by calculating the class length by dividing the difference between the highest and lowest values on the scale by the number of rating levels, i.e., $(5 - 1) \div 5 = 0.80$. Based on this class length (0.80), the response levels were determined according to the following table:

Table 3. Criteria for Interpreting Mean Scores.

Mean Score range:	Interpretation Level:
From 1.00 to 1.80	Very low
Higher than (1.80) to (2.60)	Low
Higher than (2.60) to (3.40)	Moderate
Higher than (3.40) to (4.20)	High
Higher than (4.20) to (5.00)	Very high

3.4. Instrument Validation:

This refers to evaluating the study instrument (the questionnaire) by assessing its validity and reliability. The following are the results of the questionnaire's validity and reliability:

3.4.1. Assessment of Instrument Validity:

Validity is one of the fundamental principles upon which any designed scale is based. To ensure the validity of the study instrument and that it measures what it was designed to measure, its validity was confirmed in two ways: face validity (arbitrators' validity) and Internal Consistency Evidence of the instrument, as follows:

3.4.1.1. Face and Content Validity: To verify the face validity and content validity of the study instrument, the questionnaire in its initial form was presented to a group of expert reviewers with expertise in educational technologies, kindergartens, curricula, mathematics teaching methods, and early childhood teachers, numbering (8) reviewers, in order to benefit from their opinions and observations on the suitability of the questionnaire's themes and items to the study's objectives, the clarity of its formulation and its linguistic integrity, and its suitability to the nature of the early childhood stage, The suitability of the five-point Likert scale used was assessed. Based on the reviewers' comments and suggestions, the necessary modifications were made, including deletion, addition, and rewording of some paragraphs, so that the study instrument (questionnaire) in its final form consisted of (20) statements. Thus, Following the assessment of face validity and the necessary revisions, the questionnaire was administered to a pilot sample for further evaluation to verify its internal consistency and reliability.

3.4.1.2. Item–Total Correlations: The internal consistency of the questionnaire was verified by administering it to a pilot sample of (30) early childhood teachers in public schools, outside the main study sample. Pearson correlation coefficients were calculated between the score of each item and the total score of its respective axis, as well as between the score of each axis and the total questionnaire score. This was done to examine the correlations between the items and their respective dimensions, as well as between each dimension and the total questionnaire score, as shown in Table (4).

Table 4. Pearson Correlation Coefficients Between Questionnaire Items, Their Corresponding Dimensions, and the Overall Questionnaire Score

Degree of Educational Technology Use		The importance of employing modern educational technologies		Barriers to Educational Technology Integration	
Questionnaire Item	Correlation coefficient	Questionnaire Item	Correlation coefficient	Questionnaire Item	Correlation coefficient
1	0.797**	8	0.783**	15	0.734**
2	0.789**	9	0.776**	16	0.699**

3	0.733**	10	0.791**	17	0.754**
4	0.746**	11	0.801**	18	0.718**
5	0.797**	12	0.683**	19	0.748**
6	0.757**	13	0.811**	20	0.729**
7	0.737**	14	0.709**	-	-
overall correlation	0.818**	overall correlation	0.805**	overall correlation	0.792**

**Significant at the level of (0.01) * Significant at the level of (0.05)

Table (4) shows that Pearson's correlation coefficients between the scores of the questionnaire items and the total score of the axis to which they belong, as well as between the scores of the axes and the total score of the questionnaire, were all positive and statistically significant at the level of (0.01), as the correlation coefficients of the items with their axes ranged between (0.683) and (0.811), While the correlation coefficients of the axes with the total score of the questionnaire ranged between (0.792) and (0.818), these results indicate a high level of internal consistency between the statements of each axis, and between the axes and the total score of the questionnaire, which supports the Internal Consistency Evidence of the study instrument and its suitability for application.

3.5. Assessment of Instrument Reliability:

Questionnaire reliability was assessed using Cronbach's alpha and split-half reliability, with the latter corrected using the Spearman–Brown formula. Table (5) shows the resulting values.

Table 5. Internal Consistency and Split-Half Reliability of the Study Questionnaire

Questionnaire topics	Number of Items	Reliability Assessment Method	
		Cronbach's Alpha	Split-Half Reliability
Degree of Educational Technology Use In developing some mathematical concepts	7	0.864	0.859
The importance of employing modern educational technologies in developing some mathematical concepts	7	0.890	0.851
Barriers to Educational Technology Integration In developing some mathematical concepts	6	0.823	0.818
Overall questionnaire	20	0.886	0.874

Table (5) shows that the reliability coefficients using Cronbach's alpha ranged between (0.823) and (0.890) for the questionnaire axes, and reached (0.886) for the questionnaire as a whole, while the reliability coefficients using the split-half method corrected by the Spearman-Brown equation ranged between (0.818) and (0.859) for the axes, and reached (0.874) for the questionnaire as a whole, All reported reliability coefficients exceeded the study's minimum acceptable threshold of 0.70 and were therefore considered acceptable, These results confirm that the study instrument demonstrates an acceptable level of reliability and internal consistency, supporting its suitability for application and subsequent analysis of the study data.

3.6. Statistical Analysis:

The Statistical Package for the Social Sciences (SPSS) was used to enter, process, and analyze the data using a number of statistical methods, as follows:

- Frequencies and percentages were used to summarize participants' characteristics and response distributions for the questionnaire items.
- Mean scores were calculated to summarize participants' responses to individual questionnaire items and dimensions.
- Standard deviations were calculated to describe the variability in participants' responses to questionnaire items and dimensions.
- Pearson correlation coefficient: used to calculate the internal consistency of the research instrument.
- Cronbach's Alpha Coefficient: used to verify the reliability of the instrument and its sub-scales.
- Spearman-Brown-Corrected Split-Half Reliability: used to verify the reliability of the research instrument and its sub-scales.

4. Results and Discussion:

The study results were obtained by collecting and analyzing the responses of the sample members to the questionnaire statements, then answering the sub-questions of the study and deriving the answer to the main question, as follows:

4.1. Findings Related to Research Question 1: Teachers' Use of Educational Technologies:

The first sub-question of the study was: "To what extent are modern educational technologies employed in developing certain mathematical concepts from the perspective of early childhood teachers?"

To answer the first sub-question, frequencies, percentages, weighted means, and standard deviations of the sample's responses to the statements in the first axis were calculated and ranked in descending order according to the weighted means. This was done to determine the degree to which educational

technology innovations are employed in developing certain mathematical concepts from the perspective of early childhood teachers. The overall mean and standard deviation for this dimension were calculated to summarize teachers' reported use of educational technologies according to the predefined interpretation criteria. The following table shows the results obtained:

Table 6. Means and Standard Deviations of Teachers' Self-Reported Use of Educational Technologies to Support Mathematical Concept Learning

No	Phrases	M	SD	Rank	Level of Technology Use
1	Use mobile learning technologies such as educational apps to develop children's mathematical concepts.	4.06	0.94	2	High
2	I utilize modern educational technologies that enhance mathematical concepts in explaining the lesson.	3.92	1.04	6	High
3	I plan the lesson's implementation using technology to build children's knowledge.	4.14	0.96	1	High
4	I consider the individual differences of children when selecting modern educational technologies.	4.02	0.99	4	High
5	I keep pace with current trends by developing my skills in using modern educational technologies.	4.04	0.99	3	High
6	I utilize modern educational technologies that help solidify mathematical concepts in children.	3.55	1.20	7	High
7	I have a strong desire to work with modern educational technologies and employ them in developing mathematical concepts in children.	3.94	1.15	5	High
Overall Mean		3.95	1.03	-	High

Table No. (6) shows that the estimates of the study sample regarding the degree of employment of educational technology innovations in developing some mathematical concepts were high, as the Mean Score reached (3.95), with a standard deviation of (1.03), which indicates the high degree of employment of early childhood teachers of educational technology innovations in developing some mathematical concepts among children.

The results also showed a relative convergence in the responses of the sample members to the axis statements, as the arithmetic means of the statements ranged between (3.55) and (4.14), all of which fell within the high level, while the standard deviations ranged between (0.99) and (1.15), indicating an acceptable degree of homogeneity in the responses of the sample members.

Item 3, "I plan to integrate educational technology into the lesson to support children's learning," received the highest mean score, with a Mean Score of (4.14) and a standard deviation of (0.96). The fact that this statement obtained the highest mean may be attributed to the teachers' awareness of the importance of prior planning to employ technology in the educational process, which helps to determine the appropriate technical tool and the method of using it in accordance with the objectives of the lesson and the nature of the mathematical concept to be developed.

Statement number (1), "I use mobile learning technologies such as educational applications to develop children's mathematical concepts," ranked second with a Mean Score of (4.06), a standard deviation of (0.94), and a high degree of application. Statement number (5), "I keep pace with the times by developing my skills to use modern educational technologies," ranked third with a Mean Score of (4.04), a standard deviation of (0.92), and also a high degree of application.

In contrast, statement number (6), "I use modern educational technologies that help solidify mathematical concepts in children," ranked last with a Mean Score of (3.55) and a standard deviation of (1.20). Despite this, it remained within the high level. Its relatively low ranking can be attributed to the fact that explaining mathematical concepts using educational technologies requires more precise planning and a variety of activities and practices that help the child repeat and apply the concept in new situations. Additionally, teachers' experience in employing technologies that support this type of learning varies.

In general, the results of the axis indicate a high level of early childhood teachers' use of new educational technologies in developing some mathematical concepts, reflecting a positive trend towards utilizing modern technologies in educational practices and providing more diverse and interactive educational experiences that are appropriate to the characteristics of children and their educational needs.

4.2. Findings Related to Research Question 2: Perceived Importance of Educational Technologies:

The second sub-question of the study was: "What is the importance of employing new educational technologies in developing some mathematical concepts from the perspective of early childhood teachers?"

To answer the question, descriptive statistics were calculated for the responses of the sample members to the statements of the second axis, and ranked in descending order according to the weighted averages, to determine the degree of importance of educational technology innovations in developing some mathematical concepts from the point of view of early childhood teachers, The overall weighted average and standard deviation for the entire axis were calculated to determine the degree of importance of employing educational technology innovations. The following table shows the results obtained:

Table 7. Means and Standard Deviations of Teachers' Perceived Benefits of Educational Technologies for Mathematical Concept Learning

No	Phrases	M	SD	Rank	Perceived Importance of Technology Integration
8	Modern educational technologies help develop mathematical concepts in children.	4.09	0.93	4	High
9	Modern educational technologies increase children's motivation to learn mathematical concepts.	4.24	0.97	2	Very high
10	Modern educational technologies help shift the teaching of mathematical concepts from rote learning to understanding and comprehension.	3.95	1.01	6	High
11	Modern educational technologies help accommodate the individual differences among children.	3.75	1.21	7	High
12	Modern educational technologies encourage active learning in children.	4.02	1.05	5	High
13	Modern educational technologies enhance the appeal of learning mathematical concepts for children.	4.17	0.91	3	High
14	Modern educational technologies facilitate the completion of teachers' tasks with less effort and time.	4.29	0.90	1	Very high
Overall Mean		4.07	0.99	-	High

Table (7) shows that the estimates of the study sample regarding the importance of employing educational technology innovations in developing some mathematical concepts were high, as the Mean Score for the entire axis reached (4.07), with a standard deviation of (0.99), which reflects the teachers' awareness of the importance of educational technology innovations in developing mathematical concepts among children.

The results also showed limited variation in the sample's ratings of the axis statements, with arithmetic means ranging between 3.75 and 4.29. Most statements fell within the high level, while two statements fell within the very high level. Standard deviations ranged between 0.97 and 1.21, indicating a relative convergence in the sample's responses regarding the importance of employing modern educational technologies in developing certain mathematical concepts in early childhood.

Statement No. (14) "Educational technology innovations facilitate the completion of the teacher's tasks with less effort and time" came in first place among the dimension statements, with an arithmetic mean of (4.29), and a standard deviation of (0.90), and a very high degree of importance, followed by statement No. (9) "Educational technology innovations increase the level of children's motivation to learn mathematical concepts," with an arithmetic mean of (4.24), and a standard deviation of (0.90), and a very high degree of importance, This may be attributed to teachers' awareness of the practical and educational importance of new educational technologies, as they can contribute to simplifying some educational work procedures and facilitating the implementation of tasks related to planning, presentation and follow-up, as well as presenting mathematical concepts in a more diverse and interactive way, which may increase children's attention and their willingness to learn them.

Statement No. (13), "Educational technology innovations enhance the appeal of learning mathematical concepts for children," came in third place, with an arithmetic mean of (4.17), followed by statement No. (8), "Educational technology innovations help in developing mathematical concepts for children," in fourth place, with an arithmetic mean of (4.09), both of which are of high importance.

While statement number (11), "Educational technology innovations help to take into account the individual differences between children," came in last place, with an arithmetic mean of (3.75), and a standard deviation of (1.21), and with a high degree of importance, while obtaining the lowest average among the statements of the axis, which may be attributed to the fact that taking into account individual differences is not related to the educational technology itself as much as it is related to how it is employed, and the extent of the teacher's ability to diversify activities and tasks in accordance with the levels of children.

In general, the results of the axis indicate a high level of awareness among early childhood teachers of the importance of employing new educational technologies in developing some mathematical

concepts, particularly in facilitating the teacher's tasks, increasing children's motivation and enhancing it towards learning mathematical concepts.

4.3. Findings Related to Research Question 3: Barriers to Using Modern Educational Technologies:

The third sub-question of the study was: "What barriers do early childhood teachers report to using modern educational technologies in developing certain mathematical concepts?"

To answer the question, descriptive statistics were calculated for the responses of the sample members to the statements of the third axis, and they were ranked in descending order according to the weighted means, in order to reveal the most prominent obstacles that limit the use of new educational technologies in developing mathematical concepts and the degree of their impact. The arithmetic mean and standard deviation of the axis as a whole were also calculated, in order to determine the degree of impact of the obstacles in general. The following table shows the results that were obtained.

Table 8. Means and Standard Deviations of Barriers to Using Modern Educational Technologies in Developing Certain Mathematical Concepts

No	Phrases	M	SD	Rank	Level of Perceived Barrier
15	It takes a long time to prepare, design, and implement educational activities.	3.91	1.05	4	High
16	I am not keeping up with modern educational technologies.	4.09	0.86	3	Very
17	I lack conviction in the importance of educational technologies.	3.66	0.98	6	High
18	I find it difficult to choose educational technologies that cater to individual differences.	4.18	0.86	1	High
19	I believe that using educational technologies might negatively affect a child's concentration.	3.69	1.03	5	High
20	The school administration's lack of motivation and encouragement for advertisers to employ new educational technologies.	4.14	0.96	2	High
Overall Mean		3.94	1.08	-	High

The results for the third dimension indicate that participants reported a high level of barriers to using modern educational technologies in developing some mathematical concepts, as the Mean Score of

their estimates reached (3.95) with a standard deviation of (1.08), which reflects the existence of a set of obstacles that limit the employment of new educational technologies in developing mathematical concepts, This increase shows that the obstacles to employment are not limited to one aspect, but extend to aspects related to the selection of appropriate technologies, keeping up with technological developments, administrative support, and the time required to prepare and implement activities, which may affect the effectiveness of employing these technologies in the educational process.

Standard deviations ranged from 0.86 to 1.05, indicating variation in participants' responses across the items. This demonstrates a relatively low dispersion of responses and their closeness to the mean, reflecting a general agreement on the nature of the obstacles affecting the use of educational technology innovations. All items within this dimension received mean scores classified as high according to the study's interpretation criteria, with arithmetic means ranging between 3.66 and 4.18, confirming that these obstacles are significant factors influencing the use of educational technology innovations in developing mathematical concepts among children.

Among the most prominent obstacles are the difficulty in selecting innovative educational technologies that cater to individual differences, the lack of motivation and encouragement from school administrations for teachers to utilize them, and teachers' limited familiarity with modern technology and its applications. These interconnected obstacles affect a teacher's ability to choose and effectively implement appropriate technologies. Addressing individual differences among children requires knowledge of the characteristics and capabilities of various technologies, and the effective use of new technologies necessitates continuous monitoring of advancements in the field, along with support and encouragement from school administration.

The increased impact of these obstacles may be attributed to the multiplicity of technological innovations and the varying suitability of these innovations to the characteristics and needs of children, in addition to the rapid pace of their development and the continuous need for institutional support and adaptation, which may make it more difficult to employ them effectively in developing mathematical concepts.

In contrast, the item "Weak conviction among teachers regarding the importance of educational technology innovations" ranked relatively lower than the other obstacles, with a mean score of (3.66), indicating its minimal impact compared to the other indicators within the axis. Nevertheless, it remained within the high impact level. This may be attributed to the high level of teacher utilization of educational technologies, which aligns with the findings of the axis on the importance of utilizing educational technology innovations, demonstrating teachers' high Interpretation of their importance in developing mathematical concepts.

4.4. Overall Findings Related to the Main Research Question:

The main question of the study was: "What is the reality of employing new educational technologies in developing some mathematical concepts from the point of view of early childhood teachers?"

To answer the question, the arithmetic means and standard deviations for each axis of the questionnaire were extracted and arranged according to their arithmetic means. The arithmetic mean was also calculated to estimate the reality of employing new educational technologies in developing some mathematical concepts from the point of view of early childhood teachers. Table (9) shows the results that were reached.

Table 9. Summary of Mean Scores and Standard Deviations Across Questionnaire Dimensions

No	Questionnaire topics	M	SD	Interpretation
1	Degree of Educational Technology Use In developing some mathematical concepts	3.95	1.03	High
2	The importance of employing modern educational technologies in developing some mathematical concepts	4.07	0.99	High
3	Barriers to Educational Technology Integration In developing some mathematical concepts	3.94	1.08	High
Overall Mean		3.99	1.33	High

The findings for the main research question indicate that participating teachers reported a high level of use of modern educational technologies in developing some mathematical concepts, as the overall arithmetic mean of the questionnaire as a whole was (3.99) with a standard deviation of (1.33). All the axes of the questionnaire were of a high degree, as the axis of the importance of employing modern educational technologies in developing some mathematical concepts came in first place with an arithmetic mean of (4.07), This is followed by the axis of degree of employment with an arithmetic mean of (3.95), then the axis of obstacles to employing new educational technologies with an arithmetic mean of (3.94). This can be explained by the early childhood teachers' awareness of the educational and pedagogical value of these innovations, and the possibilities they provide for presenting mathematical concepts in a more attractive and interactive way, and diversifying the methods of presenting them in a manner that suits the characteristics of children and takes into account the individual differences between them, as well as their role in enhancing children's motivation and participation in learning situations.

This result is consistent with S. Al-Ghamdi's study (2022), which showed a high level of availability and use of technological innovations in the early childhood environment. It is also consistent with Al-

Rashed's study (2018), which revealed positive trends among kindergarten teachers towards the use of digital learning. This agreement can be explained by the teachers' increased awareness of the importance of educational technologies and their role in diversifying educational experiences and presenting mathematical concepts in an interactive way that suits the characteristics of children, which is supported by the high level of Perceived Importance of Technology Integration axis to (4.07).

This result is also consistent with the study by Al-Maliki and Al-Abadi (2023), which addressed kindergarten teachers' attitudes towards the use of educational technologies. The study demonstrated the need to develop a guide for teachers to employ technologies more effectively and optimally, and recommended curriculum development to align with educational technologies.

The high degree of employment of educational technology innovations can also be explained in light of the results of studies such as Al-Otaibi's study (2022) showing a high positive effect of using augmented reality technology in developing mathematical concepts, as well as Al-Warfali's study (2023) on the effectiveness of educational kits in developing mathematical concepts among children with Down syndrome who are capable of learning.

In contrast, the current study revealed a high average of obstacles to employing new educational technologies, which is partially consistent with S. Al-Ghamdi's study (2022), which indicated the existence of difficulties that hinder the use of new technologies, albeit to a moderate degree. This indicates that the two studies agree on the existence of obstacles related to employing technologies, with a difference in the level of assessment of these obstacles.

In general, the findings of this study align with previous research in confirming the importance of educational technologies and their widespread use in early childhood, as well as their role in developing children's concepts and skills. This study is distinguished by its focus on the application of modern educational technologies in developing mathematical concepts, by identifying the extent of their use, their importance, and the main obstacles that limit their application.

5. Conclusions and Recommendations:

5.1. Main Conclusions:

1. The overall mean for teachers' use of modern educational technologies in developing mathematical concepts was high ($M = 3.95$, $SD = 1.03$), indicating a high level of technology use among early childhood teachers.
2. The overall mean for the perceived importance of using modern educational technologies in developing mathematical concepts was high ($M = 4.07$, $SD = 0.99$), reflecting early childhood teachers' awareness of the importance of these technologies in supporting children's mathematical concept development.

3. The overall mean for perceived barriers to using modern educational technologies in developing mathematical concepts was high ($M = 3.94$, $SD = 1.08$), indicating that early childhood teachers perceived substantial barriers to their use.

5.2. Practical Recommendations:

- Conduct workshops and training programs for early childhood teachers on the effective use of modern educational technologies.
- Encourage early childhood teachers to integrate modern educational technologies into their teaching practices to enhance children's engagement and motivation to learn.
- Use the Early Childhood Developmental Learning Standards Guide as a reference for developing children's mathematical concepts.
- Create a supportive learning environment and provide teachers with the materials and resources necessary for the effective use of modern educational technologies.

5.3. Directions for Future Research:

- Conducting an experimental study on the effectiveness of employing generative artificial intelligence in developing mathematical concepts.
- Studying parents' perceptions of new educational technologies in developing mathematical concepts in early childhood.
- Early childhood teachers' practices in developing early childhood mathematical skills.

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Balancing AI-Driven Adaptation and Learner Self-Regulation: A Conceptual Framework for Enhancing Learning Outcomes in Generative AI-Supported Education

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The rapid proliferation of Generative Artificial Intelligence (GenAI) has expanded the potential for personalization, feedback, and immediate support within educational environments. Despite growing evidence of its ability to enhance certain learning outcomes, increased AI-driven support does not necessarily improve all cognitive and regulatory aspects; indeed, it may raise challenges regarding over-reliance and a decline in learner autonomy. This conceptual paper aims to develop a pedagogical framework to balance AI-driven adaptation with learner self-regulation in GenAI-supported educational settings. The framework was constructed based on an integrative analytical review of recent literature in the fields of GenAI in education, adaptive learning, self-regulated learning, and human-AI hybrid regulation. The framework proposes the concept of "Balanced AI-Learner Regulation," which structures the relationship across three graduated levels: AI-led regulation, co-regulation, and learner-led regulation. It also proposes the principle of "Adaptive Fading of AI Support," based on providing support according to need and then gradually reducing it as the learner's capacity for independent self-regulation grows. The paper's primary contribution lies in shifting the focus from maximizing GenAI usage to designing a pedagogical balance that preserves autonomy, self-regulation, and critical thinking alongside the improvement of academic performance.

Keywords: Generative Artificial Intelligence; Adaptive Learning; Self-regulated learning; human-AI coordination; learning outcomes; learner autonomy.

1. Introduction

Generative AI has rapidly transformed educational environments, demonstrating the ability to generate content, explain concepts, provide feedback, respond instantly to learners' questions, and personalize certain aspects of the learning experience. This development is part of a broader shift in educational AI toward systems that are increasingly capable of personalization, interaction, and responsiveness to learners' characteristics and needs (S. Wang et al., 2024). However, the educational value of these technologies is determined not merely by their technical capacity to produce answers, but by how they are integrated into an instructional design that sustains the learner's cognitive engagement.

Recent aggregated evidence indicates that Generative AI (GenAI) has positive effects on learning, yet it also reveals significant variability in these effects. In a systematic review and meta-analysis of experimental and quasi-experimental studies, Han et al. (2025) found a moderate positive impact of GenAI on learning outcomes, with substantial variation depending on educational level, discipline, intervention duration, and context. Similarly, Chen and Cheung (2025) demonstrated positive effects on academic achievement, higher-order thinking, and motivational aspects, whereas no significant impact was observed regarding metacognition. These findings suggest that enhancing learner performance through GenAI does not necessarily foster the ability to independently monitor and regulate one's own learning.

This issue takes on particular significance when linking artificial intelligence to the concept of Self-Regulated Learning (SRL). Self-regulation is not limited to the successful completion of tasks; rather, it encompasses the learner's ability to set goals, plan, select strategies, monitor comprehension and performance, and subsequently reflect on outcomes and adjust strategies as needed (Panadero, 2017). Given Generative AI's (GenAI) capacity to perform an increasing number of these functions on the student's behalf, the central pedagogical question becomes not whether AI can support learning, but rather which functions it should support and which should remain the learner's responsibility.

A systematic review by Xia et al. (2026) demonstrated that GenAI can support multiple stages of self-regulation, ranging from setting learning goals and searching for resources to problem-solving and receiving feedback. Applied studies have also shown that pedagogically designed GenAI systems can support aspects of self-regulated learning (Ng et al., 2024). However, the ease of obtaining answers and guidance may cause the system to shift gradually from a supportive role to one that replaces the learner's own activity a challenge highlighted in literature regarding the use of large language models in education (Yan et al., 2024).

This issue is also linked to adaptive learning. AI-powered systems can adjust the level of content, tasks, and feedback based on the learner's performance, and aggregated evidence has shown that AI-supported adaptive learning systems can positively contribute to learning outcomes (X. Wang et al., 2024). However, the adaptation performed by the system can become problematic if it results in the complete transfer of learning decisions from the learner to the system.

Molenaar (2022) introduced the concept of "Hybrid Human–AI Regulation" to address this issue, emphasizing the importance of a gradual transition from AI-led regulation to learner-led regulation. With the emergence of Generative AI (GenAI), this issue has become even more pressing, as generative systems can intervene in a far wider range of decisions and cognitive processes than traditional adaptive systems.

Accordingly, this paper proceeds from the need to rethink the relationship between AI-driven adaptation and learner-driven regulation. It proposes the "Balanced AI–Learner Regulation" framework as a conceptual extension for the context of Generative AI, focusing on the dynamic balance between the external support provided by the system and the internal responsibility retained by the learner for managing their own learning.

1.1. Research Problem:

The research problem lies in an educational tension between two simultaneous trends. On one hand, Generative AI (GenAI) and adaptive learning applications seek to enhance personalization and provide increased support and feedback tailored to the learner's needs. On the other hand, education aims to cultivate learners capable of planning, monitoring, decision-making, and independent learning.

Current evidence does not indicate that increased GenAI support automatically leads to overall improvements in learning. In a randomized controlled trial, Fütterer et al. (2026) demonstrated that GenAI interventions designed to support self-regulation yielded specific benefits regarding motivational aspects but did not result in clear differences in certain cognitive and strategic outcomes. This finding aligns with broader evidence showing that the impact of GenAI varies depending on the type of outcome, the context, and the nature of the instructional design (Chen & Cheung, 2025; Han et al., 2025).

Furthermore, the system's capacity to handle certain regulatory processes may reduce opportunities for learners to engage in these processes themselves. Thus, the issue is not a choice between using or not using artificial intelligence; rather, it lies in how to distribute the responsibility for regulating learning between the system and the learner in a way that preserves the benefits of adaptability without undermining self-regulation and autonomy.

Consequently, the research problem centers on the need for a pedagogical framework that outlines how to transition between varying levels of Generative AI (GenAI) intervention: the system provides support when necessary and involves the learner in regulating learning when their capabilities allow, with support gradually tapering off to foster learner autonomy.

1.2. Research Questions and Objectives:

The research proceeds from the following primary question:

How can a conceptual framework be constructed to achieve a pedagogical balance between AI-driven adaptation and learner self-regulation, thereby enhancing learning outcomes in educational environments supported by generative AI?

This gives rise to the following questions:

1. What are the theoretical foundations governing the relationship between AI-driven adaptation and self-regulated learning?
2. How can the responsibility for regulating learning be distributed between GenAI and the learner without undermining learner autonomy?
3. What components and principles should be included in a framework for balancing adaptive support with self-regulation?
4. How can the proposed framework guide the design of GenAI environments aimed at enhancing learning outcomes?

The primary objective is to develop a pedagogical conceptual framework for balancing AI-driven adaptation with learner self-regulation. This entails analyzing the relationship between adaptive learning and self-regulation, defining levels of responsibility for regulation, proposing pedagogical principles for the progressive provision of GenAI support, and establishing a theoretical foundation for future empirical research.

1.3. Significance of the Research:

The theoretical significance of this research lies in integrating two approaches often addressed separately: adaptive learning, which focuses on the system's responsiveness to the learner's needs, and self-regulated learning, which focuses on the learner's ability to manage their own learning process. The research also introduces the concept of "Balanced AI-Learner Regulation" to explain the relationship between these two approaches within the context of Generative AI (GenAI).

From an educational perspective, the framework shifts the focus from the extent of AI usage to a more critical question: what is the appropriate level of support, at what time, and for which learner? It

also provides a foundation to guide educators and learning environment designers in utilizing GenAI as a form of educational support, rather than a substitute for critical thinking and self-regulation.

2. Methodology:

The study adopts a conceptual research design based on an integrative, analytical literature review. It does not aim to conduct a comprehensive systematic review or statistical analysis; rather, it seeks to synthesize relevant literature to develop a new explanatory framework. This approach is well-suited for research that reorganizes existing theoretical concepts and relationships to produce a more integrated explanation or conceptual construct (Jaakkola, 2020; Snyder, 2019).

The synthesis process focused on five interconnected areas: GenAI in education, adaptive learning, self-regulated learning, human-AI regulation, and learning outcomes. Priority was given to recent peer-reviewed research specifically studies published between 2022 and 2026 in international journals indexed in Scopus and Web of Science while drawing on a limited number of older theoretical references where necessary to establish foundational concepts.

3. Theoretical Foundation:

3.1. Generative AI in Education

Generative AI (GenAI) represents a shift from systems that merely retrieve or classify information to systems capable of creating new content and engaging in natural, continuous interaction with the learner. While the literature has demonstrated its potential for content delivery, feedback, and personalization, the success of its integration depends on clear pedagogical design rather than technical capabilities alone (Liu & Zhong, 2025). Furthermore, reviews concerning large language models emphasize the importance of human oversight, AI literacy, and critical thinking when utilizing these technologies in educational settings (Yan et al., 2024).

3.2. Adaptive Learning

Adaptive learning involves tailoring the educational experience based on a learner's data, performance, and needs. This adaptation can encompass content, difficulty level, the type of feedback provided, and the sequencing of activities. A meta-analysis by X. Wang et al. (2024) demonstrated that AI-powered adaptive learning systems can improve learner outcomes, underscoring the importance of personalization as a key role for AI in education.

In the context of Generative AI (GenAI), adaptation has become more flexible, enabling the real-time creation of materials and tasks aligned with a learner's interests and specific context. Tasdelen and Bodemer (2025) demonstrated the potential of using GenAI-generated, contextually personalized

content and tasks to influence motivation and performance. However, pedagogically effective personalization should not eliminate the learner's role in making choices and decisions.

3.3. Self-Regulated Learning

Self-regulated learning encompasses cognitive, metacognitive, motivational, and behavioral processes that enable learners to direct their learning toward specific goals (Panadero, 2017). In GenAI-supported environments, the system can be utilized to facilitate goal setting, suggest strategies, provide feedback, and encourage self-reflection.

Chiu (2024) proposed methods for leveraging GenAI to support self-regulation based on motivational principles, while a study by Ng et al. (2024) demonstrated that a generative chatbot designed to support self-regulated learning (SRL) could play an educational role in science learning. However, GenAI's capacity to perform these processes underscores the need to distinguish between supporting self-regulation and replacing it.

3.4. Hybrid Human-AI Regulation

The concept of hybrid regulation forms a significant basis for the present paper. Molenaar (2022) demonstrated that adaptive systems can assume certain regulatory functions during initial stages, with control gradually shifting to the learner as their skills develop. The current paper extends this rationale to the context of GenAI where interventions become more flexible and expansive and proposes that regulation should operate through dynamic levels tailored to the learner's needs and the nature of the task.

4. Literature Review and Research Gap:

Recent studies reveal rapid progress across three interconnected areas. The first involves the use of GenAI to enhance learning outcomes; meta-analyses indicate generally positive, albeit heterogeneous, effects (Chen & Cheung, 2025; Han et al., 2025). The second concerns personalization and adaptation, as GenAI has become capable of generating experiences that are better aligned with specific contexts and individual needs (Tasdelen & Bodemer, 2025). The third area focuses on supporting self-regulated learning (SRL); a review by Xia et al. (2026) demonstrated the diverse functions GenAI can perform across the various stages of SRL.

A review by Zhu and Sari (2026) demonstrated that various AI technologies can support self-regulated learning (SRL) processes and proposed an AI-SRL framework involving both the learner and the teacher; however, it also highlighted challenges associated with employing AI in this domain. This body of literature indicates that the relationship between AI and SRL has become an advanced field of

research; consequently, merely proposing the use of Generative AI (GenAI) to support self-regulation does not, in itself, constitute a sufficient conceptual contribution.

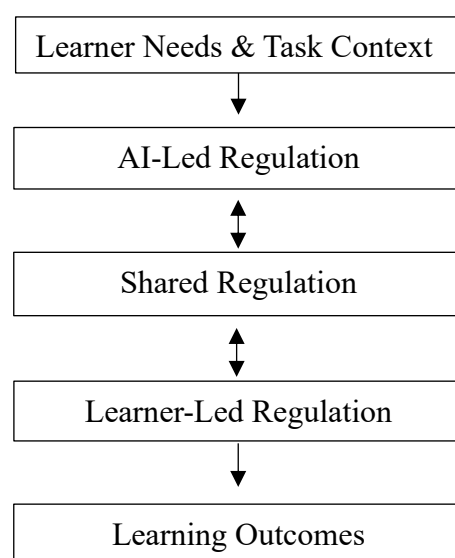
Conversely, the literature points to risks associated with the unbalanced use of AI. Farrokhnia et al. (2024) highlighted the opportunities ChatGPT offers for personalization and immediate support, alongside potential threats regarding higher-order thinking, academic integrity, and reliance on system outputs. Similarly, Yan et al. (2024) emphasized the need for a human-centered design approach when employing large language models in education.

Thus, the gap lies not in a lack of studies on GenAI, adaptation, or SRL in isolation, but rather in the need for a more specific conceptual framework that clarifies how to manage the relationship between the degree of adaptation provided by GenAI and the level of self-regulation responsibility retained by the learner. The contribution of the current study lies in developing the concept of balancing within the context of GenAI and linking it to clear levels of regulation and a principle of progressive scaffolding withdrawal.

5. Proposed Conceptual Framework: Balanced AI–Learner Regulation:

The framework is grounded in the principle that the goal is neither to maximize nor minimize AI support in absolute terms, but rather to provide the appropriate level of support based on the learner's needs while ensuring a gradual shift of responsibility toward the learner.

Figure 1. *Proposed Balanced AI–Learner Regulation Framework for Generative AI-Supported Education*



Adaptive Fading of AI Support

Higher AI Support → Greater Learner Responsibility and Self-Regulation

The framework comprises four interconnected key elements:

First, learner needs and the task context, including prior knowledge, task difficulty, performance level, and the need for guidance. These factors determine the appropriate initial level of GenAI intervention.

Second, AI-driven adaptive support, encompassing content personalization, hints, feedback, guiding questions, and the adjustment of the amount of guidance provided.

Third, learner self-regulation, involving goal setting, planning, strategy selection, comprehension monitoring, reflection, and self-assessment.

Fourth, learning outcomes; the framework prioritizes not only academic achievement but also autonomy, self-regulation, and critical thinking.

This balance is achieved across three regulatory levels:

1- AI-Led Regulation: GenAI plays a relatively prominent role when the learner requires significant support, while avoiding completely relieving the learner of cognitive engagement.

2- Shared Regulation: Responsibility is distributed between the system and the learner; GenAI provides guidance and feedback, while the learner remains responsible for making choices, providing justifications, and making key decisions.

3- Learner-Led Regulation: GenAI intervention becomes limited and available only when needed, while the learner takes greater responsibility for planning, monitoring, and evaluation. The general logic of the framework can be represented as follows:

This transition does not follow a fixed, linear path; a learner may require greater support when facing a new or more complex task, before returning to a higher level of autonomy.

Adaptive Fading of AI Support

The adaptive fading of AI support constitutes the framework's central mechanism. It ensures that support does not remain static once the learner becomes capable of performing the task independently. When a learner requires substantial support, Generative AI (GenAI) can provide explicit guidance, subsequently shifting to hints and questions, and finally to on-demand feedback, thereby gradually increasing the learner's responsibility.

In this way, GenAI does not function merely as a constant provider of answers, but rather as an adaptive scaffolder intervening when necessary and stepping back when continued intervention would hinder learner autonomy.

6. Principles and Conceptual Relationships:

The framework proposes five interconnected principles:

Principle 1: Matching support to need. The educational value of support lies not in its quantity, but in its alignment with the learner's needs and the nature of the task.

Principle 2: Support is not a substitute. GenAI should facilitate planning, monitoring, and reflection without permanently taking over these processes on the learner's behalf.

Principle 3: Gradual transfer of responsibility. Learner responsibility should increase as their capacity for independent performance and self-regulation grows.

Principle 4: Dynamic balance. There is no single, optimal level of support suitable for all learners and tasks; therefore, movement between the three levels of regulation should be permitted.

Principle 5: Learning quality transcends performance speed. The success of GenAI should not be judged solely by the quality of the answer or the speed of task completion, but also by the preservation of self-regulation, autonomy, and critical thinking.

These principles suggest that the relationship between the amount of AI support and learning outcomes may not be linear. Insufficient support may fail to meet learner needs, and appropriate support can enhance learning, whereas excessive, continuous support may diminish opportunities for self-regulation. The mixed findings of recent studies reinforce the need to empirically examine this relationship in the future, rather than assuming that more support invariably leads to better outcomes (Fütterer et al., 2026).

7. Theoretical and Educational Implications:

7.1. Theoretical Implications:

The framework offers three key theoretical contributions.

First, it links adaptive learning with self-regulated learning by viewing them as complementary forms of learning regulation: external regulation performed by the system and internal regulation performed by the learner.

Second, it develops the concept of hybrid regulation within the context of GenAI by identifying three distinct levels of regulatory relationships and linking the transitions between them to the principle of the "Adaptive Fading of AI Support."

Third, it shifts the focus of GenAI evaluation from the general question of its effectiveness to the question of the optimal distribution of regulatory responsibility between humans and AI. This shift

aligns with literature emphasizing that the effective integration of GenAI requires a sound pedagogical foundation and appropriate guidance, rather than merely making the technology available (Liu & Zhong, 2025).

7.2. Educational Implications:

The framework recommends that GenAI begin with the minimum level of support necessary to enable the learner to proceed with the task such as a hint or a guiding question before moving to a more detailed explanation. Furthermore, activities should require learners to explain their choices, evaluate system responses, and justify solutions, rather than simply reproducing GenAI outputs.

Educators can leverage AI to provide feedback and adaptive support while designing tasks that keep learners accountable for their own goals and decisions. Similarly, developers of educational systems can design adjustable levels of support, rather than relying on a single, fixed mode of assistance.

8. Future Research Agenda:

The proposed framework requires empirical testing across various educational levels and disciplines. Future research could compare the effects of AI-led, shared, and learner-led regulation on achievement, self-regulation, autonomy, and critical thinking.

It is also necessary to identify the conditions under which "adaptive fading" is most effective, examining how its impact varies based on learner expertise, task type, and prior SRL levels. Furthermore, comparing different forms of GenAI intervention—such as direct answers, hints, Socratic questioning, and reflective feedback—is crucial to determining which best sustains cognitive and regulatory engagement.

Future studies could also investigate the potential non-linear relationship between the level of GenAI support and learning outcomes, helping to identify the threshold at which support shifts from a facilitating factor to one that may foster over-reliance.

9. Study Limitations:

The proposed framework remains a conceptual construct that has not undergone empirical testing; therefore, the relationships outlined within it cannot be interpreted as proven causal links. Furthermore, this paper relies on a targeted analytical review rather than a comprehensive systematic review of all available studies.

Additionally, the field of Generative AI (GenAI) is evolving rapidly, and new system capabilities may give rise to different patterns of interaction between the learner and the technology. The

appropriate level of support may also vary depending on age group, discipline, cultural context, and the nature of the task. Consequently, the framework should be viewed as a theoretical foundation open to further development and testing, rather than a definitive model applicable to all contexts.

10. Conclusion:

This paper addressed the educational challenge of leveraging the adaptive capabilities of Generative AI (GenAI) while preserving the learner's ability to independently regulate their learning. It proceeded from the premise that improving learning outcomes should not be measured solely by the extent of support GenAI can provide, but rather by how the responsibilities for planning, monitoring, decision-making, and evaluation are distributed between the system and the learner.

The paper proposed the "Balanced AI–Learner Regulation" framework, based on three dynamic levels—AI-led regulation, co-regulation, and learner-led regulation—alongside the principle of "Adaptive Fading of AI Support" to gradually transfer regulatory responsibility to the learner.

The framework's central message is that GenAI is most educationally valuable when it acts as an adaptive scaffold supporting the learner's capacity for independent learning, rather than as a substitute for the processes the learner ought to develop and practice personally. This conceptualization provides a theoretical foundation that can guide the design of more balanced learning environments and inform future empirical studies on the relationship between AI-driven adaptation, self-regulation, and learning outcomes.

11. Declaration:

The researcher confirms that no funding was received for this research and that there are no conflicts of interest. Artificial intelligence models were used to compile the scientific references for this study.

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