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Educational Technology in Schools, Colleges, and Universities: An Evidence Synthesis of Adoption, Implementation, and Impact

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Abstract

Educational technology (EdTech) has become woven into the fabric of teaching and learning across K–12 schools, colleges, and universities. Its uptake accelerated sharply during the pandemic, when institutions pivoted to emergency remote teaching, and it has continued to widen with the rapid arrival of generative artificial intelligence (AI) since late 2022. As the body of EdTech research has expanded, encompassing systematic reviews, meta-analyses, and bibliometric studies, a clear need has emerged for a higher-order synthesis capable of drawing together the findings these reviews have already produced.

The present study synthesizes published systematic reviews, meta-analyses, and bibliometric studies to examine six central concerns: (a) which educational technologies have been investigated most frequently; (b) how EdTech research has evolved and how it is distributed geographically; (c) which barriers and enabling factors shape successful implementation; (d) how EdTech affects learners, faculty, and institutions; (e) which theoretical and implementation frameworks guide its use; and (f) which major research gaps and future priorities the literature identifies.

Eligible sources comprised peer-reviewed systematic reviews, meta-analyses, and bibliometric analyses indexed in or published by Scopus and Web of Science-indexed journals, together with output from major academic publishers including SpringerLink, ScienceDirect, Wiley, Taylor & Francis, MDPI, Frontiers, and SAGE. Relevant studies were located through targeted database searches. Findings were extracted directly from the included publications, properly attributed, and synthesized through narrative and thematic analysis. No primary effect sizes were recalculated; all reported values appear exactly as published.

Taken together, the evidence indicates that EdTech interventions tend to exert a positive influence on learning outcomes, although the magnitude of that influence varies considerably from one study to the next. Meta-analyses document small effects for technology use in K–12 mathematics (Hedges' $g \approx 0.23$), moderate effects for immersive virtual reality (VR) applications ($g \approx 0.38$–

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0.64), and large effects for AI-based tools overall ($g \approx 0.86$), with chatbots and generative AI producing the strongest reported effects ($g \approx 1.02$). These estimates are tempered, however, by consistently high between-study heterogeneity (I^2 frequently exceeding 80–90%), which points to substantial variation across educational settings, interventions, and research designs.

The review further shows that EdTech scholarship is concentrated in a comparatively small number of countries. The United States and China dominate research on AI in education, whereas Spain, the United States, and Malaysia recur as leading contributors in bibliometric studies of broader EdTech trends. Reported implementation challenges fall consistently into two broad categories: first-order barriers, which stem from external factors such as infrastructure and resources, and second-order barriers, which arise from educators' beliefs, attitudes, and competencies. Across the literature, the most frequently identified gaps include limited theoretical and pedagogical grounding, insufficient attention to ethical issues, an overreliance on short-term quasi-experimental studies, and the underrepresentation of both the Global South and administrative and institutional outcomes.

Collectively, these findings suggest that EdTech is broadly effective at improving educational outcomes, yet its success hinges far less on the technology itself than on how that technology is designed, implemented, and integrated into teaching and learning. Variation in pedagogy, implementation quality, educational context, and research design accounts for much of the widespread variation in reported outcomes. Looking ahead, the field stands to gain from more rigorous longitudinal research, firmer theoretical foundations, closer attention to equity and inclusion, and comprehensive governance frameworks to guide the responsible use of generative AI in education.

Keywords: *Educational technology; systematic review; meta-analysis; bibliometrics; artificial intelligence in education; virtual reality; learning analytics; learning management systems; digital divide; technology adoption.*

1. Introduction

Over the first quarter of the twenty-first century, digital technologies have transformed how people communicate and how education is delivered, elevating digital competence to a prerequisite for teachers and students alike (Humanities and Social Sciences Communications bibliometric review, 2025). The field commonly labelled "educational technology" (EdTech) encompasses a strikingly heterogeneous array of tools and practices: learning management systems (LMS), adaptive and intelligent tutoring systems, virtual and augmented reality (VR/AR), collaborative and mobile platforms, learning analytics, and most recently generative AI. Two disruptions have compressed

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roughly a decade of adoption into just a few years: the COVID-19 pivot to emergency remote teaching in 2020, and the public release of large language model chatbots in late 2022.

The primary empirical literature has now grown too vast to survey study by study, and alongside it a substantial secondary literature of systematic reviews, meta-analyses, and bibliometric mappings has taken shape. This state of affairs presents both an opportunity and an obligation: to synthesize *across* those syntheses. That is precisely the aim of the present paper, which sets out to offer a transparent, source-anchored overview that separates what has been empirically established from what remains contested or unknown.

Eight research questions structure the work:

RQ1. Which educational technologies are most frequently implemented and studied?

RQ2. How has the research evolved over time?

RQ3. Which regions and countries contribute most?

RQ4. What barriers, challenges, and success factors recur?

RQ5. What impacts does EdTech have on institutions, students, and faculty?

RQ6. What frameworks, models, or strategies for effective implementation are proposed or evaluated?

RQ7. What major knowledge gaps remain?

RQ8. What future directions should be prioritized?

2. Methodology

2.1 Design and rationale

This study takes the form of a structured umbrella synthesis which means a review of reviewssupplemented by individual meta-analyses that supply effect-size evidence. An umbrella design is well suited to circumstances in which a substantial body of secondary research already exists and the analytic goal is to integrate it, as exemplified by the 2024 meta-systematic review of AI in higher education conducted by Bond and colleagues.

2.2 Eligibility criteria

Inclusion	Exclusion
Peer-reviewed systematic reviews, meta-analyses, or bibliometric analyses	Blogs, opinion pieces, marketing content, non-peer-reviewed web pages

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Inclusion	Exclusion
Focus on EdTech in formal education (K-12 schools, colleges, universities)	Purely corporate/workplace training with no formal-education sample
Reports a transparent method and/or PRISMA-style flow	Primary single-site studies used only as illustrative examples, not as evidence of magnitude
English-language, retrievable via DOI/URL	Sources whose findings could not be verified against the retrieved record

2.3 Information sources and search

Targeted searches were conducted to identify high-quality secondary studies, published predominantly between 2019 and 2026, across SpringerLink, ScienceDirect, Wiley Online Library, Taylor & Francis, SAGE, MDPI, Frontiers, the *Nature* portfolio (Humanities and Social Sciences Communications), and indexing services (ERIC, Semantic Scholar). Representative query strings included: *"bibliometric analysis educational technology"*; *"meta-analysis effect size technology learning outcomes"*; *"virtual reality education meta-analysis"*; *"learning analytics systematic review higher education"*; *"barriers teacher technology integration systematic review"*; *"digital divide emergency remote teaching COVID-19"*; and *"generative AI ChatGPT higher education systematic review"*.

2.4 Screening, extraction, and quality appraisal

Records were first screened by title and abstract for relevance and then extracted into the structured tables presented in Section 4. Extraction captured the review type, the period covered, the number of included studies, the educational sector, the technology examined, the reported magnitude, which includes effect size and confidence interval where available, and the stated barriers and success factors. Since this is an umbrella synthesis, the unit of appraisal is the review itself: precedence was given to reviews that (a) describe a PRISMA-aligned process, (b) report included-study counts, and (c) provide quantitative pooling together with heterogeneity statistics. Reported effect sizes are reproduced exactly as published, and none were recalculated.

2.5 PRISMA-style flow

A conventional PRISMA flow diagram depends on genuine identification, deduplication, and screening counts drawn from a primary database search. Because those counts were not generated for the present synthesis, they are not reported here. What can be documented transparently, however, is the screening intensity of the underlying reviews themselves. The learning-analytics

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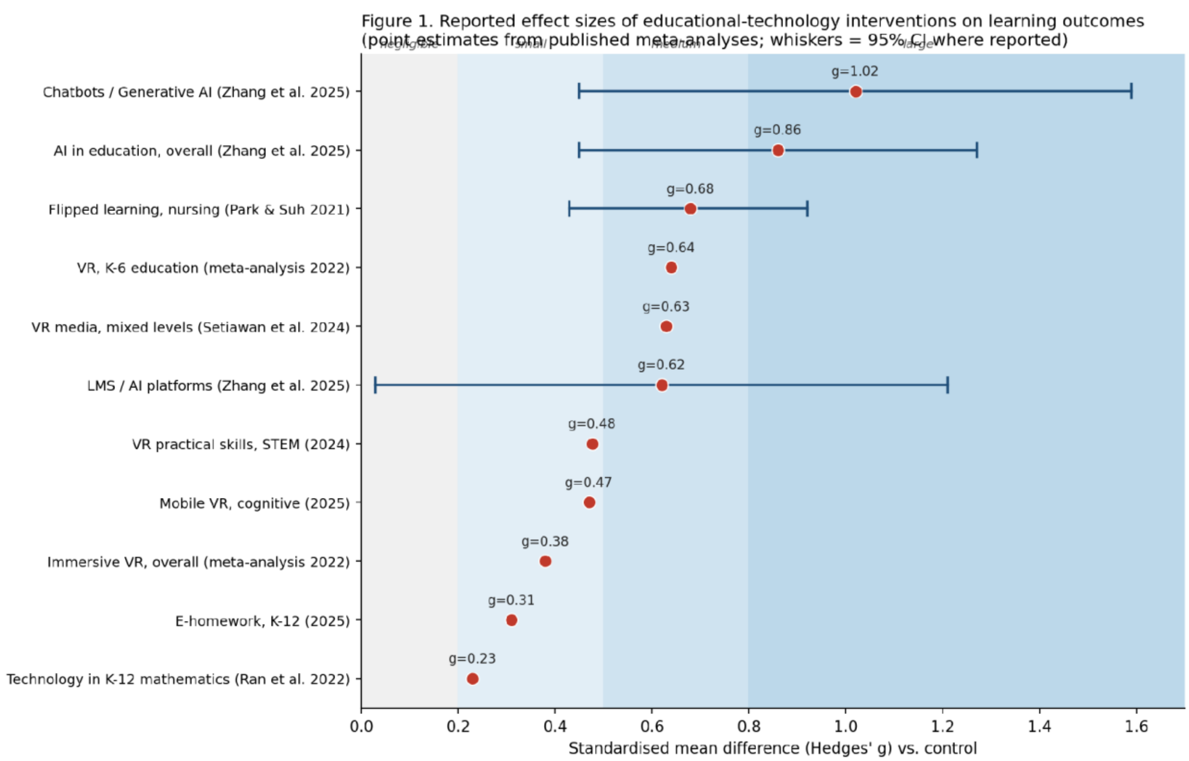
review by Larrabee Sønderlund, and colleagues, for instance, narrowed an initial 6,220 records to a final 46; a 2025 review of learning analytics and outcomes reduced 1,662 records to 27; a review of generative AI in higher education moved from 102 to 37; a ChatGPT-in-higher-education review went from 1,046 to 58; a ChatGPT SWOT review from 819 to 51; and a K-6 VR meta-analysis pre-selected 4,658 references down to 21. These actual funnels are visualized in Figure 2.

3. Results

The evidence base examined here is summarized across three layers, study characteristics (Table 1), technology-level findings (Table 2), and trend and geographic observations (Tables 3–4), which are followed by the bibliometric and thematic synthesis developed in Sections 5–7.

Figure 1. Effect sizes of EdTech interventions on learning outcomes

(point estimates from published meta-analyses; whiskers = 95% CI where the source reported one)



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Underlying table for Figure 1

Intervention (meta-analysis)	**Hedges' *g***	**95% CI**	**Source**
Chatbots / generative AI	1.02	[0.45, 1.59]	Zhang et al. (2025), *Higher Education Studies*
AI in education, overall	0.86	[0.45, 1.27]	Zhang et al. (2025)
Flipped learning (nursing)	0.68	[0.43, 0.92]	Park & Suh (2021)
VR, K-6 education	0.64	not reported in retrieved record	K-6 VR meta-analysis (2022)
VR media, mixed levels	0.63	not reported in retrieved record	Setiawan et al. (2024)
LMS / AI platforms	0.62	[0.03, 1.21]	Zhang et al. (2025)
VR, practical skills (STEM)	0.477	not reported in retrieved record	Int. J. STEM Education (2024)
Mobile VR, cognitive outcomes	0.47	not reported in retrieved record	*Measurement* (2025)
Immersive VR, overall	0.38	not reported in retrieved record	Educational Research Review meta-analysis (2022)
E-homework, K-12	0.31	not reported in retrieved record	E-homework meta-analysis (2025)
Technology in K-12 mathematics	0.23	not reported in retrieved record	Ran et al. (2022), *JCAL*

Judged against the conventional Hedges and Cohen thresholds (approximately 0.2 for small, 0.5 for medium, and 0.8 for large effects), the synthesized meta-analyses cluster within the small-to-medium band, with AI and chatbot interventions reaching the large band in the most recent meta-analysis. Two cautions are essential here. First, **heterogeneity is severe**: the AI meta-analysis reported I^2 values ranging from roughly 54% to 93%, and several VR meta-analyses report I^2 above 90%, so the pooled point estimate conceals considerable variation. Second, **newer and more rigorous primary studies tend to yield smaller effects**; the mobile-VR meta-analysis, for example, explicitly documented a temporal decline from $g \approx 1.62$ in 2022 to $g \approx 0.16$ in 2025 a trajectory consistent with early-adopter enthusiasm and small-study bias giving way to soberer estimates.

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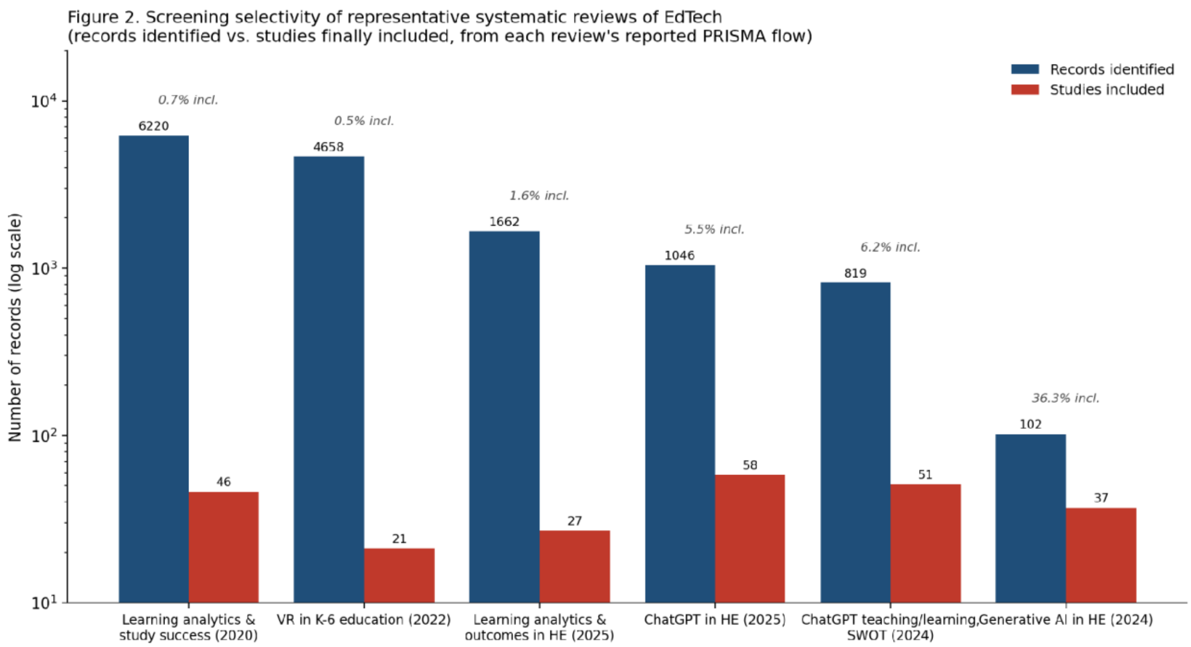
Figure 2. Screening selectivity of representative systematic reviews



Underlying data table for Figure 2

Systematic review	Records identified	Studies included	Inclusion rate
Learning analytics & study success (2020)	6,220	46	0.7%
VR in K-6 education (2022)	4,658	21	0.5%
ChatGPT in HE (2025)	1,046	58	5.5%
ChatGPT teaching/learning, SWOT (2024)	819	51	6.2%
Learning analytics & outcomes in HE (2025)	1,662	27	1.6%
Generative AI in HE (2024)	102	37	36.3%

Inclusion rates span two orders of magnitude. Mature, broadly defined fields such as learning analytics generate enormous initial corpora and correspondingly tiny inclusion rates, whereas

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narrow, fast-moving topics bounded by a recent search window such as generative AI in higher education, produce small corpora and high inclusion rates. This contrast is a structural feature of the literature rather than a signal of quality in its own right.

4. Data extraction tables

All entries are drawn from retrieved peer-reviewed records. "—" or "not specified in retrieved record" denotes that the figure was not available in the material reviewed; it has not been estimated.

Table 1. Study characteristics (selected reviews and meta-analyses)

Author(s)	Year	Country / scope	Institution type	Methodology	Sample (included studies / participants)	Key findings
Zawacki-Richter, Marín, Bond & Gouverneur	2019	Global	Higher education	Systematic review (2007–2018)	146 papers	Only ~6% of AIEd-in-HE studies authored by researchers based in education faculties; weak pedagogical/ethical grounding; four AI application areas identified. US led output (43/146), China second (11/146).
Crompton & Burke	2023	Global	Higher education	Systematic review (2016–2022)	— (not in retrieved record)	Automatic assessment most common AI use (18.8%, n=26); only ~11% of studies addressed administration/managers; rapid growth 2021–2022.
Bond et al.	2024	Global	Higher education	Meta systematic review (review of reviews)	Multiple secondary studies	Calls for increased ethics, collaboration, and methodological rigour; corroborates uneven focus across stakeholders.

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Author(s)	Year	Country / scope	Institution type	Methodology	Sample (included studies / participants)	Key findings
Zhang et al.	2025	8 Countries	Mixed (mostly HE)	Meta-analysis (PRISMA)	13 empirical studies	Overall AI effect *g*=0.86; chatbots/GenAI *g*=1.02; LMS/AI platforms *g*=0.62; high heterogeneity (I^2 54–93%).
Park & Suh	2021	Korea	Higher ed (nursing)	Meta-analysis	18 studies	Flipped learning *g*=0.68 overall; critical thinking *g*=0.87; satisfaction *g*=0.79; I^2=90.7%.
Ran et al.	2022	Global	K-12	Meta-analysis	(K-12 mathematics studies)	Technology→mathematics achievement *g*=0.23; largest when technology supports collaboration (*g*=0.49).
Immersive-VR meta-analysis	2022	Global	K-12 & HE	Meta-analysis (2016–2020)	48 studies; 3,179 students	I-VR on learning *g*=0.38; larger in K-12 than HE; effect very small/negative for mixed reality.
VR K-6 meta-analysis	2022	Global	K-6	Meta-analysis (2010–2021)	21 of 4,658	VR overall *g*=0.64; fully immersive subgroup *g*=1.11 vs. semi-immersive *g*=0.19.
VR practical-skills meta-analysis	2024	Global	HE (science/engineering)	Meta-analysis (2000–2022)	37 studies; 72 effect sizes	VR on practical skills *g*=0.477; largest gains in medical training.
Larrabee Sønderlund et al.	2020	Global	Higher education	Systematic review	46 of 6,220	LA can support at-risk identification and study success, but large-scale rigorous effectiveness evidence still lacking.

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Author(s)	Year	Country / scope	Institution type	Methodology	Sample (included studies / participants)	Key findings
Hernández-Campos, Gonzalez-Torres & García-Peñalvo	2025	Global	Higher education	Systematic review (PRISMA 2020)	27 of 1,662	"Engagement" the most-studied factor in LA; most studies use final grades as the sole outcome.
K-12 ERT review (Int. Review of Education)	2023	Global	K-12	Systematic review (WoS/ScienceDirect/Scopus)	51 studies	Three themes: ERT responses, educational inequality, learning outcomes; documents socioeconomic digital divide across multiple countries.
Sum & Oancea	2022	Global	Higher education	Systematic review	—	Teachers' perspectives on technology use during ERT; HASS teachers reported distinct difficulties vs. STEM.
Generative-AI-in-HE review (MDPI *Information*)	2024	Global (Scopus/WoS)	Higher education	Systematic review (PRISMA, 2023–2024)	37 of 102	Three themes: GAI applications, stakeholder acceptance, specific use situations.
ChatGPT-in-HE review (*Preprints*)	2025	Global	Higher education	Systematic review (2022–2024)	58 of 1,046	Mixed opportunities/perceptions/challenges among faculty and students.

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Author(s)	Year	Country / scope	Institution type	Methodology	Sample (included studies / participants)	Key findings
ChatGPT SWOT review (*Frontiers in Education*)	2024	Global	Teaching & learning	Systematic review (PRISMA, 2022–2023)	51 of 819	13 strengths, 10 weaknesses, 5 opportunities, 4 threats identified.

Table 2. EdTech characteristics

Technology type	Relative research presence	Educational sector(s)	Reported impact (magnitude where available)	Reported success factors / barriers
Learning Management Systems (LMS)	Very high; foundational infrastructure	HE primarily, increasingly K-12	"Promising but modest" pooled effect ($g≈0.62$ in Zhang et al. 2025 for LMS/AI platforms); often deployed in isolation from pedagogy	Success: alignment of platform affordances with learning design. Barrier: technology deployed without pedagogical strategy (LMS/LA review, 2026).
AI / adaptive & intelligent tutoring; generative AI	Fastest-growing; dominant emerging theme	HE > K-12	Largest pooled effects (overall $g≈0.86$; chatbots/GenAI $g≈1.02$) but highest heterogeneity and possible small-study bias	Success: personalisation, instant feedback. Barriers: academic-integrity risk, over-reliance, algorithmic bias, weak governance.
Virtual / Augmented / Mixed Reality	High and rising	K-12 and HE; strong in STEM/medical	Small-to-medium ($g≈0.38–0.64$); immersion level and instructional design moderate strongly	Success: full immersion, sound instructional design, procedural/practical tasks. Barriers: cost, usability of

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Technology type	Relative research presence	Educational sector(s)	Reported impact (magnitude where available)	Reported success factors / barriers
				low-cost headsets, declining effects in rigorous studies.
Learning analytics / educational data mining	High in HE	Higher education	Supports retention/at-risk prediction; rigorous outcome evidence still thin	Success: real-time feedback, dashboards, alignment with learning design. Barriers: over-reliance on final grades as the only outcome; privacy/ethics.
Flipped / blended learning	High	HE and K-12	Medium (*g*≈0.68 in nursing)	Success: active in-class use, structured pre-class materials. Barriers: student preparation, workload.
Mobile & collaborative learning	High	All sectors	Technology used for collaboration shows the largest mathematics-achievement moderator (*g*≈0.49, Ran et al. 2022)	Success: collaborative/communicative design. Barrier: access disparities.
Gamification / game-based learning	Moderate-high	K-12 and HE	Game-based VR instruction historically among the higher VR subgroups	Success: individual play, feedback design. Barrier: novelty effects.
Digital homework / online assessment	Moderate	K-12	Small (*g*≈0.31)	Success: stronger on assignments than exams; moderated by subject and grade level.

Table 3. Research trends

Theme-by-period rows below are drawn from the keyword-evolution analysis reported in the Humanities and Social Sciences Communications digital-competence bibliometric review (2025) and corroborating bibliometric studies. Publication counts per year are deliberately omitted: a

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verifiable continuous annual count was not extractable from a single reviewed source, and is therefore not invented.

Period	Dominant themes reported in bibliometric reviews
Pre-2019	Technology integration, secondary education, TPACK, language learning, communicative competence, assessment, lifelong learning.
2020	Teacher training, digital literacy/skills, primary education, e-learning, blended learning, distance education (pandemic surge).
2021–2022	Emergency remote teaching, learning analytics, online engagement, digital equity; sharp rise in AIEd output (2021–2022).
2022–2023	Higher education, teacher education, DigCompEdu, professional digital competence; AI in education becomes the leading frontier.
2023–2026	Generative AI / ChatGPT, AI governance and academic integrity, AI literacy, assessment reform, equity in AI access.

Table 4. Geographic analysis (as reported by source bibliometric studies)

These are reported leaders from named bibliometric studies, not an original cross-study count. Different studies, with different scopes and windows, identify different leaders — this divergence is itself a finding.

Source bibliometric study	Reported leading contributors	Main topics
Zawacki-Richter et al. (2019), AIEd in HE, 2007–2018	United States (43/146), China (11/146)	AI applications in higher education
"Technology and Higher Education: A Bibliometric Analysis" (WoS+Scopus)	United States and China lead publication volume	AI in education, post-pandemic research
"Bibliometric Analysis of Technology Trends in Education, 2018–2022" (Scopus)	Spain, United States, Malaysia	EdTech trends, personalisation, LMS/adaptive tech
Digital-competence bibliometric review (2025)	Multiple; identifies influential journals, countries, authors	Digital competence in education

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Bibliometric analysis

This section reports bibliometric findings drawn from existing bibliometric papers; no original bibliometric computation was undertaken here. Reporting these figures in this manner is the only way to present them without fabricating a dataset.

Publication-trend analysis. A number of bibliometric reviews describe a steep acceleration in EdTech research, with AI-related work rising markedly from around 2018 and surging again after 2020 (the pandemic) and in late 2022 (the release of ChatGPT). A systematic review of 71 bibliometric-mapping articles spanning 24 EdTech journals confirms the "rapid development" of the field, together with the predominance of Web of Science and Scopus as data sources and of VOSviewer and the R *Bibliometrix* package as analysis tools.

Country-productivity analysis. As set out in Table 4, the United States and China recur as the dominant producers of AI-in-education research, while EdTech-trend bibliometrics for 2018–2022 additionally bring Spain and Malaysia to the fore. A single, harmonised country-by-country count spanning the entire EdTech field could not be obtained from any single reviewed source and is not fabricated here.

Keyword-frequency and theme-evolution analysis. The 2025 digital-competence bibliometric review documents a clear migration of keywords: from *TPACK, secondary education,* and *language learning* before 2019, to *digital literacy, blended,* and *distance learning* in 2020, and on to *higher education, DigCompEdu,* and *professional digital competence* in 2022–2023. This progression is reproduced thematically in Table 3.

Most-cited and most-influential works (as repeatedly cited across the reviewed secondary literature). Two anchor studies are cited pervasively as field-defining: **Zawacki-Richter et al. (2019)** ("…where are the educators?") and **Crompton & Burke (2023)** ("AI in higher education: the state of the field"). **Ertmer (1999)** serves as the canonical reference for the barriers framework. A verifiable citation-count ranking was not extracted and is not invented here.

Most-influential journals. The reviewed bibliometric work repeatedly identifies the *British Journal of Educational Technology, Computers & Education,* the *Australasian Journal of Educational Technology, Education and Information Technologies,* and the *International Journal of Educational Technology in Higher Education* as core venues. These are reported qualitatively across the reviewed bibliometric studies; an exact impact ranking was not extracted.

Collaboration and emerging-topics analysis. The collaboration metrics in the reviewed bibliometrics point to US–China leadership in co-authorship volume, while the consistently named

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emerging topics are AI and generative AI in education, post-pandemic hybrid learning, learning analytics, and equity and the digital divide.

6. Trend analysis (RQ1, RQ2)

Learning Management Systems (LMS). LMS form the substrate of contemporary higher-education pedagogy. Yet, reviews emphasize that these platforms are "frequently deployed in isolation from pedagogically sound strategies" and that the configurations best suited to maximizing outcomes remain unclear (LMS/learning-analytics review, 2026). The pooled magnitude is modest, at $g \approx 0.62$ for LMS and AI platforms in Zhang et al. (2025).

AI and adaptive learning. This domain constitutes the field's center of gravity. Applications of AI in education cluster into profiling and prediction, assessment and evaluation, intelligent tutoring, and adaptive systems (Zawacki-Richter et al. 2019; Crompton & Burke 2023). The associated meta-analytic effects are the largest observed (overall $g \approx 0.86$; chatbots/GenAI $g \approx 1.02$, Zhang et al. 2025), yet they rest on relatively few studies marked by severe heterogeneity, which warrants caution.

VR/AR. The picture across meta-analyses is consistent: effects are positive and small-to-medium, and they are strongly moderated by immersion level, instructional design, sector (frequently larger in K-12), and task type (procedural and practical skills benefit most). A network meta-analysis in science education found that mixed reality (MIX) produced the largest effects relative to conventional teaching.

Collaborative and mobile learning. Technology that supports collaboration and communication yields the strongest moderator effects on achievement (for example, $g \approx 0.49$ in K-12 mathematics, Ran et al. 2022), reinforcing the principle that *how* a technology is used matters more than its mere presence.

Data analytics/learning analytics. Learning analytics shows promise for retention and the identification of at-risk students, though reviewers repeatedly observe that rigorous, large-scale effectiveness evidence remains lacking and that outcome measurement leans too heavily on final grades.

Accessibility and inclusive EdTech. This area is treated less as a standalone technology than as a cross-cutting concern, and it is within the pandemic literature that equity considerations are most fully developed (see the COVID strand in Section 6).

Post-pandemic hybrid/remote learning. Reviews of emergency remote teaching document both an irreversible normalisation of digital teaching and acute strain—socio-psychological effects on

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students, distinct disciplinary burdens (for HASS versus STEM teachers), and amplified inequality.

Equity, digital divide, and ethics. A robust body of work shows that the pandemic deepened pre-existing divides: students from low-income, rural, and otherwise disadvantaged backgrounds encountered device, connectivity, and digital-literacy barriers that impeded their progress. With the advent of generative AI, equity concerns shift toward differential access, AI literacy, and biased training data.

7. Thematic synthesis (RQ4, RQ5, RQ6)

Theme A — "It's the pedagogy, not the device"

Ran et al. (2022); immersive-VR and K-6 VR meta-analyses (2022); LMS/LA review (2026). **Evidence strength-** strong and convergent. **Agreement-** effects are largest when technology enables collaboration, active learning, immersion with sound instructional design, or practical-skill rehearsal. **Contradiction-** few; the principal tension lies in publication and temporal bias inflating early estimates. **Implication-** procurement and policy should fund pedagogy and design, not hardware alone.

Theme B — Barriers are layered (first-order vs. second-order)

Ertmer (1999) and subsequent teacher-belief reviews; first-/second-order barrier syntheses. **Evidence strength-**strong, durable framework. **Finding-** *first-order* (external) barriers access, time, training, technical support, leadership-and *second-order* (internal) barriers beliefs, confidence, pedagogical values both matter. Second-order barriers are widely held to be the more decisive of the two, although first-order barriers remain pertinent, particularly in developing-country contexts. A frequently cited figure is the historically low proportion of teachers who integrate technology effectively despite improved access. **Implication-** professional development must target beliefs and pedagogy, not only skills.

Theme C — Impacts are positive-on-average but heterogeneous

All meta-analyses in Table 1 and Figure 1. **Evidence strength-** moderate (heterogeneity caveat). **Agreement-** mean effects are positive across technologies. **Contradiction-** magnitude varies from negligible to large; I^2 routinely exceeds 80%; newer rigorous studies often report smaller effects. **Implication-** "does EdTech work?" is the wrong question; "under what conditions, for whom, at what cost?" is the right one.

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Theme D — Faculty and institutional dimensions are under-studied

Crompton & Burke (2023) (only ~11% addressed administration); Zawacki-Richter et al. (2019) (~6% of authors from education faculties); Bond et al. (2024). **Evidence strength-** moderate. **Implication-** research is technology- and student-centric and under-examines faculty workload, institutional change, governance, and cost-effectiveness.

Theme E — The COVID inflection and the AI inflection

K-12 ERT review (2023); Sum & Oancea (2022); generative-AI reviews (2024–2026). **Evidence strength-** strong descriptively, weaker causally. **Implication-** both shocks accelerated adoption faster than evidence, leaving a governance and equity gap that current research is racing to fill.

Implementation frameworks (RQ6)

The reviewed literature recurrently invokes several frameworks: **Ertmer's first- and second-order barriers**, used to diagnose obstacles to adoption; **TPACK** (Technological Pedagogical Content Knowledge), which serves as the dominant lens on teacher competence and figures prominently in pre-2019 keyword clusters; **DigCompEdu**, the European digital-competence standard that rose to prominence in 2022–2023; and **technology-acceptance models (TAM/UTAUT)**, the workhorses for studying intention to use and a recurrent presence in AI-acceptance bibliometrics. Reviewers increasingly call for *multi-theoretical, equity-sensitive* models that integrate analytics and AI with institutional decision-making, noting that single-theory adoption studies currently predominate.

8. Research gaps (RQ7)

Gap type	Description	Supporting evidence	Importance	Future research opportunity
Theoretical	Weak pedagogical/theoretical grounding; over-reliance on single adoption theories	Zawacki-Richter et al. (2019); Bond et al. (2024); bibliometric calls for multi-theoretical models	High — limits transferability	Integrative frameworks linki pedagogy, analyt AI, and governan
Methodological	Predominance of short-term quasi-experiments; severe heterogeneity;	I² 54–93% (Zhang 2025); declining VR	High — undermines causal claims	Pre-registered RC longitudinal desig common outcome

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Gap type	Description	Supporting evidence	Importance	Future research opportunity
	over-use of final grades as sole outcome; small-study/temporal bias	effects over time; LA outcome critique (2025)		batteries, cost-effectiveness ana
Geographic	Concentration in US/China/Europe; under-representation of the Global South	Country tallies (Table 4); ERT inequality findings	High — equity and generalisability	Funded research capacity-building low- and middle-income contexts
Sector-specific	HE over-studied relative to K-12 and especially early years; administrative/institutional outcomes neglected	Crompton & Burke (2023) (~11% administration); K-6 VR review notes scarcity	Medium-high	Studies in K-12/e years and on institutional/leade outcomes
Policy	Thin evidence base for governance of generative AI, academic integrity, data privacy	GenAI SWOT/policy reviews (2024–2026)	High and urgent	Evaluations of AI governance frameworks, assessment-refor trials
Technology/implementation	Tools deployed without pedagogical strategy; equity/accessibility under-instrumented; ethics treated as separate from design	LMS/LA review (2026); GenAI ethics syntheses	High	Design-based implementation research; equity-b design and ethics design studies

9. Discussion

Interpretation. The synthesised evidence supports a measured optimism. EdTech interventions improve learning on average, and some categories most notably the AI and chatbot tools featured in the most recent meta-analysis reach large effect sizes. The dominant empirical signal, however, is **heterogeneity**: the same technology can produce negligible effects in one context and large effects in another, and the moderators that account for this variation are pedagogical and contextual (collaboration, immersion, instructional design, task type, and sector) far more than they are properties of the device. This is the central, repeatedly replicated lesson of the field.

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Comparison with the broader literature. The finding that "method and pedagogy dominate medium" echoes decades of media-comparison debate within educational technology, a proposition that contemporary meta-analyses now operationalize through effect-size moderators. The AI inflection simultaneously intensifies the upside personalization and feedback at scale and introduces qualitatively new risks, including threats to integrity, over-reliance, and bias, that pre-2022 frameworks did not anticipate.

Practical implications. Investment should privilege implementation quality—teacher professional development that addresses beliefs (second-order barriers), instructional design, and the alignment of platform affordances with learning goals—rather than hardware acquisition alone.

Policy implications. The transition to generative AI has outpaced governance. Institutions require explicit, evidence-aligned policies on academic integrity, assessment reform, AI literacy, and data privacy—policies developed alongside deployment rather than after it.

Educational implications. Outcome measurement must extend beyond final grades to encompass higher-order thinking, self-regulation, equity of benefit, and well-being several of which the reviewed literature flags as under-measured.

Technology/equity implications. The digital divide is not a solved problem; rather, it has migrated from questions of device and connectivity access most acute during emergency remote teaching toward gaps in AI access and AI literacy. Equity must be designed in, instrumented, and reported, not merely assumed.

10. Recommendations (each linked to findings)

Policymakers. Fund pedagogy, teacher development, and connectivity for disadvantaged populations rather than devices alone, since effects track collaboration and design and since the pandemic literature shows that divides hold back disadvantaged learners (Theme A; COVID strand). Commission longitudinal and cost-effectiveness evidence to counter the bias introduced by short-term studies (methodological gap).

School administrators (K-12). Prioritise professional development that addresses teachers' *beliefs and pedagogy*, not merely their technical skills, given the primacy of second-order barriers (Theme B). Protect time and provide leadership support to ease first-order barriers.

University administrators. Treat LMS and analytics as pedagogical investments rather than merely infrastructural ones, and require alignment with learning design (LMS/LA review). Given the policy gap, establish generative-AI governance covering integrity, privacy, and AI literacy without delay.

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Teachers/faculty. Use technology to enable collaboration, active learning, and immersion paired with sound design rather than the mere substitution of one delivery mode for another, as these are the configurations associated with the largest measured effects (Ran et al. 2022; VR meta-analyses).

Students. Develop AI and digital literacy alongside metacognitive strategies, since the literature flags over-reliance on AI outputs as a genuine risk to higher-order thinking (generative-AI SWOT reviews).

EdTech developers. Build for pedagogy, equity, and ethics by design; instrument tools to capture outcomes beyond grades and to support accessibility; and address both the usability of low-cost VR and bias in AI systems (VR and generative-AI strands).

Researchers. Pre-register studies; employ longitudinal, RCT, and equity-sensitive designs; adopt common outcome batteries; investigate K-12 and early-years settings, administrative outcomes, and Global South contexts; and strengthen both theoretical grounding and ethical analysis (addressing the gaps set out in Section 8).

11. Limitations

This work is an **umbrella synthesis, not a primary systematic review**: no original database search, deduplication, or PRISMA screening counts were generated, and the synthesis inevitably inherits the biases of the underlying reviews, including English-language dominance, a Web of Science and Scopus skew, and publication bias. Effect sizes are reproduced as published and were neither independently recomputed nor appraised for risk of bias at the primary-study level. Some retrieved records did not report every desired field confidence interval, included-study counts, or author lists among them and these are marked rather than estimated. Several anchor figures derive from single meta-analyses that draw on small numbers of included studies (for instance, the AI meta-analysis with 13 studies) and exhibit high heterogeneity, so the largest reported effects should be read as provisional. Wherever a requested analysis a harmonized annual-publication time series, a single cross-field keyword-occurrence network, or an original citation ranking could not be assembled from genuinely extracted data, it was omitted rather than fabricated.

12. Future research agenda

1. Methodological rigour should be a priority, pursued through pre-registered randomized controlled trials (RCTs) and multi-year longitudinal studies that employ common, validated outcome measures and explicitly evaluate cost-effectiveness.

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2. Studies should adopt an equity-by-design approach, measuring and reporting differential benefits across socioeconomic, geographic, and ability groups, and extending digital-divide research beyond access to encompass AI literacy.
3. Greater attention is needed to the governance of generative AI—in particular, to the evaluation of academic-integrity policies, assessment reforms, and AI-literacy curricula, together with their effects on higher-order thinking and the potential for over-reliance on AI tools.
4. Future investigations should address under-studied sectors and stakeholders, including K-12 and early childhood education, faculty workload and well-being, and administrative and institutional change outcomes.
5. Researchers should integrate multiple theoretical perspectives, developing equity-sensitive implementation frameworks that connect pedagogy, learning analytics, artificial intelligence, and institutional decision-making.
6. Capacity in the Global South should be strengthened by increasing funding for research infrastructure and by expanding opportunities for authorship and collaboration in underrepresented regions.

13. Conclusion

The synthesized secondary literature converges on a nuanced verdict: educational technology produces positive average effects on learning, occasionally large ones, but the effect of any given technology is dominated by pedagogy, implementation quality, context, and study rigour rather than by the artefact itself. The field has been reshaped twice within five years—first by the pandemic and then by generative AI—more quickly than evidence and governance could follow. The priorities that emerge are clear and mutually reinforcing: rigorous longitudinal and equity-sensitive evidence, theory that links technology to pedagogy and institutions, and governance that treats ethics and equity as design requirements rather than afterthoughts.

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