

Article

Will the Educational Metaverse Reproduce or Reduce Educational Inequities? A Systematic Review of Four Decades of Digital Learning Evidence (1981–2024)

André Gopal

Department of Digital Arts, University of the Witwatersrand, Johannesburg, South Africa

Corresponding author: André Gopal, andre.gopal@wits.ac.za

CITATION

Gopal A. Will the Educational Metaverse Reproduce or Reduce Educational Inequities? A Systematic Review of Four Decades of Digital Learning Evidence (1981–2024). *Metaverse*. 2026; 7(4): m260010. <https://doi.org/10.54517/m260010>

COPYRIGHT

Copyright © 2026 by author(s).

Metaverse is published by Asia Pacific Academy of Science Pte. Ltd. This work is licensed under the Creative Commons Attribution (CC BY) license. <https://creativecommons.org/licenses/by/4.0/>

Abstract: Discussion of the educational metaverse has expanded rapidly, yet much of the equity discourse in this emerging field remains forward-looking and speculative. Claims that immersive virtual environments will democratise access, transcend geography, or close attainment gaps are commonly made but rarely grounded in empirical evidence about how earlier technology-enhanced learning has performed across differently-resourced contexts. This systematic review addresses that gap by synthesising four decades of evidence on online learning, gamified education, and metaverse-related research (1981–2024) to assess whether the educational metaverse is more likely to reduce or reproduce educational inequities. Following PRISMA 2020 guidelines, two complementary search strings were applied across IEEE Xplore and Scopus, yielding a final analytical corpus of 76 sources. Each source was coded for geographic context, depth of equity engagement, period of publication, and population resource context. All findings reflect patterns within the technology-targeted, conventionally indexed corpus; they were produced by a single reviewer and should be read as indicative patterns accordingly. Three patterns characterise the corpus. First, no source engaged equity as its central analytical concern (0/77); only 5 (6.6%) engaged equity substantively, while 56 (73.7%) made no engagement at all. Second, equity engagement is wholly a post-2010 phenomenon, absent before 2010 (0/13), entering at low intensity in 2010–2019 (7/32, 21.9%), and rising sharply during the pandemic period 2020–2023 (11/27, 40.7%). Third, among empirical studies, equity engagement tracks the resource context of the population studied rather than the modality of the technology: 0/14 studies of well-resourced populations engaged equity at any level, while 4/6 studies of under-resourced populations did so. These patterns should be read as what is visible within the technology-enhanced learning literature as conventionally indexed. These findings indicate that the technology-enhanced learning literature, as conventionally indexed, has not produced a body of work in which equity is centrally examined. The metaverse-in-education discourse, predominantly produced from well-resourced settings, is structurally unlikely to engage equity unless deliberately reoriented. The review reframes speculative equity claims as testable empirical propositions and proposes an evidence-led agenda for the next phase of metaverse-related educational research.

Keywords: Educational metaverse; Digital divide; Educational inequity; Online learning; Gamified education; Systematic review; Equity in technology-enhanced learning

1. Introduction

The educational metaverse has emerged as one of the most actively discussed prospects in contemporary education research. As immersive technologies — virtual, augmented, and mixed reality — converge with persistent online environments, scholars and policymakers have begun to articulate visions of education unbounded

by geography, institutional walls, or the constraints of two-dimensional screens [1–4]. Within these visions, equity claims have become a recurring rhetorical anchor. Immersive environments are said to democratise access to expert teaching, to enable learners from remote regions to enter shared learning spaces, and to overcome the social isolation that characterised emergency remote teaching during the Covid-19 pandemic [5].

These claims are forward-looking and largely speculative. Empirical research on educational applications of the metaverse remains nascent, with most studies reporting on small-scale pilots in well-resourced settings [6–8]. Concentrations of metaverse-education research in a handful of high-income economies mean that the evidence on which equity claims are built is geographically narrow before it has had the opportunity to broaden. At the same time, an older and substantially larger body of literature on online and gamified learning has spent four decades documenting how technology-enhanced education actually performs across differently-resourced contexts. That literature contains evidence of access barriers, infrastructure constraints, educator preparedness gaps, and design failures that have repeatedly undermined the equity ambitions of preceding educational technologies [9,10].

Reading these two literatures together raises a question that the current metaverse-in-education discourse has not adequately addressed: if four decades of digital learning research has documented how technology can both narrow and widen educational inequities, what does that record predict for the educational metaverse? Will the immersive environments now being prototyped reproduce the patterns documented in earlier waves of educational technology — extending opportunity in some settings while deepening disadvantage in others — or do they have the structural properties to break those patterns?

This review synthesises evidence from a corpus of 79 records (77 unique sources after deduplication) published between 1981 and 2024 across three converging fields — online learning, gamified education, and metaverse-related educational research — to assess what the available evidence permits us to claim about equity in the educational metaverse. Rather than proposing a new conceptual model of immersive learning, the review treats the existing body of evidence as the basis for an equity audit: what barriers have been documented, how have they been addressed, which are likely to transfer or intensify in metaverse environments, and under what conditions might such environments plausibly reduce rather than reproduce inequity? The review's contribution is to reframe the speculative equity claims of the metaverse-education literature as empirical propositions that can be tested against four decades of accumulated evidence.

2. Background

2.1. The Educational Metaverse

The term metaverse originates in Stephenson's [11] novel *Snow Crash*, in which it described a persistent virtual world for user interaction. Contemporary usage refers to a set of immersive, three-dimensional, interconnected environments accessed through head-mounted displays, mobile augmented reality, or desktop-based virtual worlds [3,4]. The educational metaverse comprises applications of these environments to teaching, training, and learning, ranging from simulation-based skill development to avatar-mediated classrooms.

Three properties distinguish metaverse-based learning from earlier digital

modalities. First, it is shared: multiple users co-occupy a virtual environment in real time, enabling synchronous interaction [1]. Second, it is persistent: the environment continues to exist between sessions, and learners' actions within it accumulate. Third, it is immersive: spatial audio, embodied avatars, and three-dimensional rendering produce a sense of presence absent from text- or video-based platforms.

These properties are frequently presented in the literature as the basis for equity claims. Co-presence is said to overcome geographical isolation. Immersion is said to compensate for absent infrastructure such as laboratories. Persistence is said to enable continuous, learner-paced engagement that classroom timetables cannot accommodate [2,3]. Whether these properties produce equitable outcomes in practice is a different question — one that requires empirical grounding rather than technological extrapolation.

2.2. The Digital Divide and its Evolution

As used throughout this review, equity refers to the condition in which all learners have what they need to participate meaningfully in technology-enhanced education, irrespective of socioeconomic status, geography, disability, language, or cultural background; inequity denotes the systematic failure of that condition. Access refers to the material and technical preconditions for participation (devices, connectivity, hardware). Inclusion encompasses the broader social, pedagogical, and design conditions required for full and effective participation. The digital divide is used in the three-level sense described below and is treated as the principal operationalisation of educational inequity in technology-mediated contexts. Educational inequity in technology-enhanced contexts has been theorised most extensively through the digital divide literature. Early formulations centred on physical access: who had a computer and an internet connection, and who did not [12,13]. As access expanded unevenly through the 2000s, scholars distinguished a second-level divide in skills and usage: even where access was present, differences in digital literacy, content engagement, and creative use of technology produced unequal benefit [14,15]. More recently, a third-level divide has been articulated in terms of outcomes — the tangible educational, economic, and social returns that flow from technology use, which remain differentially distributed even where access and skills are equalised [16,17].

Educational technology research has tracked this evolution. Where early work focused on connectivity and device availability [18,19], later work examined design features that determine whether access translates into learning gain — interface complexity, scaffolding, language and cultural relevance, and the assumed prior knowledge embedded in instructional materials [9,10,20]. The persistent finding across this literature is that equitable educational outcomes from technology require deliberate design: access alone does not produce equity, and may in some cases widen existing gaps where instructional design assumes learner conditions that not all learners share [21].

The educational metaverse extends rather than resolves these dynamics. Hardware costs are higher than for two-dimensional online learning. Bandwidth requirements are more demanding. The skills required to navigate three-dimensional interfaces add a further dimension of digital literacy. The platforms within which immersive learning currently operates are predominantly commercial, raising questions of cost, subscription dependence, and platform governance that previous educational technologies — many of which were free or institutionally provided —

did not pose to the same degree.

2.3. Online Learning and Gamified Education as Equity Sites

Online learning, defined here as education delivered through two-dimensional web-based platforms with predominantly asynchronous interaction, is the most extensively studied modality of technology-enhanced education. Its equity record is mixed. Online delivery has expanded access to learners in geographically remote, professionally constrained, or institutionally underserved positions [22,23]. It has also exhibited consistent failure modes: low completion rates among learners with limited prior digital experience; reduced engagement and social presence relative to face-to-face instruction; and widened performance gaps during emergency remote teaching where infrastructure was uneven [5,24,25]. The pandemic period offered a natural experiment in technology-enhanced learning at scale, and the consensus finding from that experiment is that online learning amplified pre-existing inequities at least as often as it reduced them [26,27].

Gamified education — the application of game design elements such as points, rewards, challenges, and narrative structures to learning activities — has been advanced as a mechanism for sustaining the engagement that asynchronous online learning frequently fails to achieve [28–30]. The equity record of gamification in education is less developed, but available evidence suggests that gamified designs produce variable outcomes depending on alignment with learning objectives, cultural fit, and learner familiarity with the underlying game conventions [31,32]. Gamification, in other words, is not an equity-neutral pedagogical strategy: it carries implicit assumptions about learner motivation, competition, and engagement style that may not transfer uniformly across contexts.

Read together, these two bodies of literature offer something the metaverse-in-education discourse currently lacks: a sustained empirical record of how technology-enhanced learning interacts with educational inequity over time. That record is the analytical resource on which this review draws.

2.4. Distinguishing Modalities

The relationship between online learning, gamified education, and metaverse-based learning is one of nested affordances rather than discrete categories. Gamification can be applied to two-dimensional online platforms or to immersive three-dimensional environments. Metaverse environments can be highly gamified or minimally so. Online learning can be enhanced with gamified elements without becoming immersive. The evidence base reviewed here therefore spans a continuum rather than three sealed categories, and the equity-relevant findings move across modality boundaries (**Table 1**). The corpus assembled for this review reflects that continuum, including: metaverse-specific environments (persistent three-dimensional shared spaces); VR/AR/XR applications in educational contexts; desktop virtual worlds (e.g., Second Life); gamified digital learning platforms; general online learning and e-learning; and foundational or theoretical works that span modalities. These are not treated as equivalent in the synthesis: metaverse-specific and immersive sources inform the RQ3–RQ4 transferability analysis directly, while online learning and gamification sources provide the empirical record against which metaverse equity prospects are assessed. **Appendix A** allows readers to identify sources by modality, though a formal modality coding variable was not added to this review (see §7.1).

Table 1. Comparison of Online Learning, Gamified Online Learning, and Metaverse-Based Learning

Feature	Online Learning	Gamified Online Learning	Metaverse-Based Learning
Spatial environment	Two-dimensional interfaces	Two-dimensional interfaces with game layers	Persistent three-dimensional space
User interaction	Predominantly asynchronous	Asynchronous with synchronous game events	Synchronous co-presence; avatar-based
Equity-relevant access conditions	Internet, device, basic digital literacy	As online plus game-convention literacy	As online plus VR/AR hardware, bandwidth, three-dimensional interface skills
Predominant platform model	Mixed institutional and commercial	Mixed institutional and commercial	Predominantly commercial

3. Rationale and Research Questions

3.1. The Need for this Study

The case for an equity-grounded synthesis of metaverse-relevant educational technology research rests on three observations. First, claims about the metaverse's equity-enhancing potential have proliferated faster than empirical evidence to support them, and the empirical evidence that does exist is geographically and demographically narrow. Second, recent reviews of metaverse-in-education research have foregrounded technical capabilities, pedagogical innovations, and conceptual frameworks while engaging only marginally with equity, access, and inclusion concerns [4,6,7]. Third, the older online learning and gamified education literatures contain substantial empirical content on equity dynamics that has not been systematically brought to bear on metaverse-related design and policy questions.

The Covid-19 pandemic accelerated and exposed these dynamics. The rapid pivot to emergency remote teaching demonstrated both the reach and the limitations of existing online platforms. Where infrastructure, devices, and digital literacy were available, online learning sustained instructional continuity. Where they were absent, learning losses concentrated among already-disadvantaged populations [26,27,33]. The pandemic record is directly relevant to metaverse-based learning because it indicates how technology-enhanced education performs under conditions of scale, urgency, and uneven resourcing — conditions that any future expansion of immersive learning will also encounter.

This review therefore synthesises evidence from online learning, gamified education, and metaverse-related research to ask a focused question: what does four decades of digital learning evidence (1981–2024), as conventionally indexed, permit us to claim, with appropriate calibration, about the educational metaverse's likely performance on equity?

3.2. Research Questions

RQ1. How is equity engaged across the technology-enhanced learning literature reviewed, and how has that engagement shifted over the period 1981–2024?

RQ2. What barriers to equitable participation in technology-enhanced learning are documented in the corpus, and which are likely to intensify, persist, or recede in metaverse-based learning?

RQ3. What design, pedagogical, and policy responses to documented barriers are evidenced in the corpus, and how transferable are these responses to immersive

contexts?

RQ4. Under what conditions might metaverse-based learning plausibly reduce rather than reproduce educational inequities?

4. Methodology

4.1. Research Design

This study employed a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [34]. The PRISMA framework provides a structured approach to identifying, screening, synthesising, and reporting research literature with emphasis on transparency and replicability. Given the interpretive nature of the review's research questions — which require analytical synthesis across heterogeneous evidence streams rather than meta-analytic effect estimation — the review adopts a configurative rather than aggregative orientation [35].

4.2. Search Strategy

The literature search was conducted in June 2024 using two academic databases: IEEE Xplore and Scopus. These databases were selected for their comprehensive coverage of technology, education, and interdisciplinary research, and for their capacity to support replicable search strategies. Their limitations for an equity-focused synthesis are addressed in §4.7 and §7.1 and treated explicitly in the analytical interpretation of findings.

Two complementary search strings were applied independently to both databases and the results combined. String 1 was technology-targeted, covering metaverse, virtual and immersive reality, gamification, game-based learning, online learning, and technology-enhanced learning in educational contexts. String 2 added an explicit equity dimension, pairing online and digital learning terms with equity, access, inclusion, digital divide, and socioeconomic descriptors. The two strings are reproduced below.

String 1: ("educational metaverse" OR metaverse OR "virtual world" OR "immersive virtual environment*" OR "immersive learning" OR "virtual reality" OR VR OR "augmented reality" OR AR OR "mixed reality" OR MR OR "extended reality" OR XR OR "online learning" OR "e-learning" OR "digital learning" OR "technology-enhanced learning" OR "computer-assisted learning" OR "distance education" OR "remote learning" OR "gamified learning" OR gamification OR "game-based learning" OR "serious game*") AND (education OR educational OR learning OR teaching OR classroom* OR school* OR universit* OR "higher education" OR student*) AND (equity OR inequity OR inequality OR inequalities OR "educational inequality" OR "educational inequity" OR "digital divide" OR access OR accessibility OR inclusion OR inclusive OR exclusion OR disadvantage* OR marginali* OR "socioeconomic status" OR SES OR poverty OR "low-income" OR "resource-constrained" OR "under-resourced" OR rural OR "attainment gap*" OR "achievement gap*" OR participation OR retention OR "learning outcome*")*

String 2: ("online learning" OR "e-learning" OR "digital learning" OR "technology-enhanced learning" OR "computer-assisted learning" OR "distance education" OR "remote learning" OR "blended learning") AND (education OR learning OR teaching OR classroom OR school* OR universit* OR "higher education" OR student*) AND (equity OR inequity OR inequality OR "digital divide" OR access OR accessibility OR inclusion OR exclusion OR disadvantage* OR "socioeconomic*

status" OR SES OR poverty OR "low-income" OR rural OR "under-resourced" OR "achievement gap" OR "attainment gap*" OR "learning outcome*" OR retention OR participation)*

Both strings were applied to IEEE Xplore and Scopus in June 2024 and limited to records published in English from 1981 onwards. String 1 returned 122 records from IEEE Xplore and 78 from Scopus (total: 200); String 2 returned 97 records from IEEE Xplore and 71 from Scopus (total: 168). Combined across both strings and databases, 368 records were identified, reducing to 323 after manual deduplication (45 duplicates removed). The start year of 1981 was selected to allow inclusion of foundational scholarship on technology adoption, learner motivation, and digital game-based learning that continues to underpin contemporary work on immersive and metaverse-oriented education [36–39]. A small number of 2024 records were surfaced through citation tracing after the search cutoff and retained where they met eligibility criteria.

String 1 is technology-targeted; String 2 is equity-targeted. Together they address the review’s question: what does the technology-enhanced learning literature as it exists yields when read through an equity lens, not what an equity-targeted search would surface. The implications of this choice for findings are addressed in §7.1.

4.3. Eligibility Criteria

Documents were included if they examined education in relation to (a) metaverse-related or immersive environments (e.g., virtual worlds, VR/AR/MR/XR), (b) gamified education or game-based learning implemented in digital settings, and/or (c) online learning research that reports learner experience, adoption, design factors, or implementation constraints relevant to metaverse-based learning design. Documents were excluded if they were unavailable online, not in English, duplicated across databases, or did not address educational outcomes or user experience implications relevant to the review questions. **Table 2** summarises inclusion and exclusion criteria using the Population, Intervention, Comparison, Outcome (PICO) framework.

For borderline cases, studies were included when they met at least one of the following conditions: (a) they examined metaverse-related or immersive learning environments in an educational context, even if gamification was not the primary focus; (b) they investigated gamification or digital game-based learning in educational contexts, even where the term “metaverse” was absent, provided that the mechanisms (e.g., feedback, challenge, progression, social interaction) were transferable to immersive digital environments; or (c) they examined online learning adoption, engagement, social presence, or implementation constraints that directly inform feasibility and design requirements for metaverse-based learning.

Table 2. Inclusion and Exclusion Criteria

Criterion	Category	Inclusion Criteria	Exclusion Criteria
P	Population/Context	The study must focus on an educational, training, or learning context, including K-12, Higher Education, Vocational Training, or Professional Development.	Studies focused purely on clinical/therapeutic interventions, entertainment/leisure, or commercial marketing without a defined educational objective.

Continuation Table:

Criterion	Category	Inclusion Criteria	Exclusion Criteria
I	Intervention / Evidence stream	The study must investigate at least one of the following evidence streams in an educational context: Component 1: A Metaverse-related environment (i.e., Desktop Virtual Worlds, Immersive VR, or Augmented Reality). Component 2: The purposeful application of Gamification Mechanics (e.g., rewards, points, badges, leaderboards, quests, narrative) to the learning activity.	Studies focused purely on entertainment/leisure without an educational objective; studies reporting only technical system performance (e.g., latency, rendering speed) with no learner experience or educational outcome; and studies with no clear learning context.
	Comparison	1. Metaverse-related or immersive environments (e.g., virtual worlds, VR/AR/MR/XR) used for teaching and learning; and/or 2. Gamified education or game-based learning implemented in digital learning contexts (including online or immersive settings); and/or 3. Online learning / technology-enhanced learning research that reports learner perceptions, outcomes, or implementation constraints directly relevant to metaverse-based/immersive learning design (e.g., engagement, motivation, social presence, collaboration, digital literacy, technology acceptance). Studies must compare the intervention against a control group (e.g., traditional instruction, non-gamified virtual environment) OR studies must be a descriptive evaluation of the intervention.	Not applicable (descriptive studies are included).
O	Outcome	The study must report on one or more educational outcomes relevant to learner experience or learning effectiveness: Cognitive Outcomes (e.g., knowledge acquisition, problem-solving, critical thinking), Affective Outcomes (e.g., motivation, engagement, attitude), or Behavioral Outcomes (e.g., collaboration, skill transfer).	Studies focused exclusively on technical performance (e.g., network latency, rendering speed) without reporting educational or user experience findings.

Continuation Table:

Criterion	Category	Inclusion Criteria	Exclusion Criteria
S	Study Design	Empirical studies (quantitative, qualitative, mixed-methods), systematic reviews, meta-analyses, and seminal conceptual/theoretical works that directly inform technology-enhanced learning adoption, gamified learning, immersion, or learner motivation in educational contexts.	Editorials, commentaries, opinion pieces, conference abstracts (if full paper is not retrievable), book reviews, and dissertations not available through an indexed database.

4.4. Screening Process

The two search strings yielded 368 records in total (String 1: 122 IEEE Xplore, 78 Scopus; String 2: 97 IEEE Xplore, 71 Scopus). Forty-five duplicates were removed manually, yielding 323 records for screening. An additional 11 records identified through citation tracing were assessed against the same eligibility criteria [34]. Of the 323 screened records, 210 were excluded at title/abstract stage. Of the 113 full texts reviewed, 45 were excluded (not relevant/no educational outcomes: $n = 30$; intervention/population criteria not met: $n = 15$). All 11 citation-tracing records were retained, yielding 79 records (68 from databases + 11 from citation tracing) at the PRISMA inclusion stage. A PRISMA 2020 checklist is provided as supplementary material. The complete list of sources in the analytical corpus, with each source's coding on the four variables described in §4.5, is provided in Appendix A.

During subsequent analytical coding (§4.5), two records were identified as duplicate publications and consolidated, and one source — an editorial (Kirschner, 2002) — was removed as inconsistent with the stated exclusion criteria (**Table 2**, Study Design row), yielding 76 unique sources for synthesis. All percentages reported in the Results section refer to this 76-source analytical corpus unless otherwise stated.

All screening and analytical coding was conducted by the sole author without inter-rater reliability assessment. This is a meaningful constraint: without independent rating by a second reviewer, confidence in individual coding assignments — particularly for the interpretive equity-engagement variable — is limited to the rubric and the per-source confidence ratings in Appendix A. The constraint is partially mitigated by (a) explicit, pre-specified eligibility criteria; (b) full documentation of inclusion/exclusion reasoning; and (c) a two-stage screening process. Readers are advised to treat the precise distribution of equity-engagement codes as indicative rather than definitive. This limitation is addressed further in §7.1. **Figure 1** presents the PRISMA 2020 flow diagram.

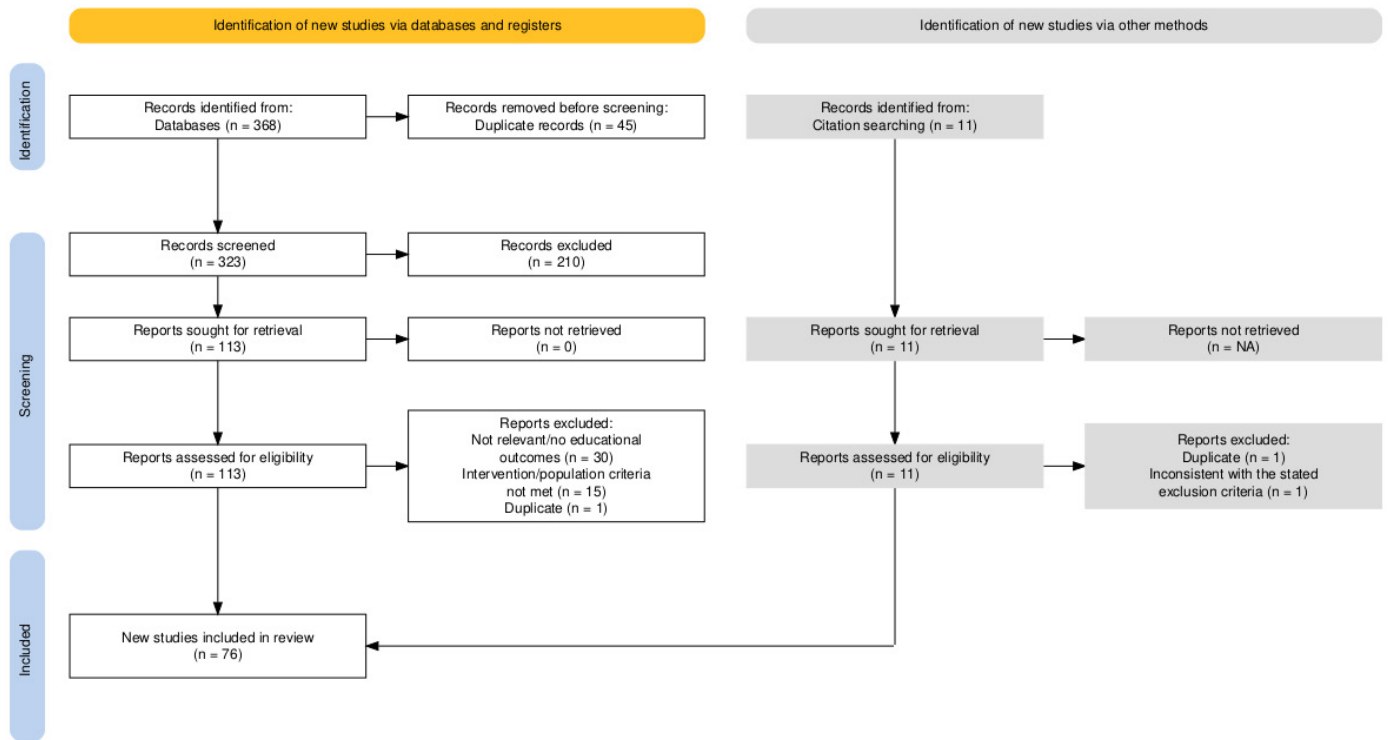


Figure 1. PRISMA 2020 Flow Diagram.

4.5. Coding Scheme

To support equity-focused analysis, each included source was coded on four variables in addition to the relevance assessment retained from the original screening (Table 3).

Geographic context identifies the location of the empirical evidence reported in the source, classified as Global South, Global North, Mixed, or Not Specified, with a separate code (Not Applicable) for non-empirical works. Classification followed United Nations and World Bank income-group conventions.

Equity engagement records the depth at which the source addresses equity, access, divide, marginalisation, or related concerns. Codes are Central (equity is the primary focus or a primary finding), Secondary (equity is meaningfully engaged among multiple themes), Mentioned (equity is referenced briefly without analytic engagement), or Absent.

Period of publication bins sources by decade: 1981–1999, 2000–2009, 2010–2019, 2020–2023, and 2024+. The final bin captures sources published in 2024, surfaced through citation tracing after the original search end date and retained where they met eligibility criteria.

Population resource context applies to empirical studies and characterises the resource conditions of the study population: Well-resourced, Under-resourced, Mixed, or Not Specified. Theoretical, conceptual, and methodological works are coded as Not Applicable.

Each coding decision was assigned a confidence rating (High, Medium, or Low) based on the clarity of information available in the source. Of 76 unique sources, 25 (32.9%) were coded with High confidence, 39 (51.3%) with Medium confidence, and 12 (15.8%) with Low confidence. Given that all coding was conducted by a single reviewer (see §4.4), readers should treat Low-confidence codings with particular caution. Patterns in the Results section are robust to changes in individual Low-

confidence codings because the headline patterns concern absences rather than borderline classifications; sensitivity is noted in §7.1. Per-source codings for all 76 corpus members are tabulated in Appendix A. Sources in Appendix A are stratified into five categories: (1) peer-reviewed empirical studies; (2) systematic reviews and meta-analyses; (3) conceptual or theoretical works; (4) policy, industry, or grey literature documents; (5) background or foundational works. These categories serve as the evidence-level indicator for the synthesis; empirical and review sources carry greater evidential weight in pattern claims.

Table 3. Coding Rubric

Variable	Codes and definitions
Geographic context	Global South / Global North / Mixed / Not Specified / N/A. Based on UN and World Bank income classifications. Refers to the location of the empirical study, not the affiliation of the author.
Equity engagement	Central / Secondary / Mentioned / Absent. Records the depth at which the source addresses equity, access, the digital divide, or marginalisation.
Period of publication	1981–1999 / 2000–2009 / 2010–2019 / 2020–2023 / 2024+.
Population resource context	Well-resourced / Under-resourced / Mixed / Not Specified / N/A. Applies to empirical studies; characterises infrastructure, device, and digital access conditions of the study population.

4.6. Synthesis Approach

Synthesis was conducted in three stages. First, descriptive statistics were generated across the four coding variables to characterise the corpus. Second, thematic synthesis [40] was conducted within each research question, with the coded variables used to disaggregate findings by geographic context, equity engagement, and period. Third, an equity-transferability analysis was performed: barriers and responses identified in online learning and gamified education literatures were assessed for likely behaviour in metaverse environments based on documented mechanisms and stated boundary conditions. Source-type stratification (see §4.5) informed the weight assigned to evidence during synthesis: empirical studies and systematic reviews served as the primary basis for pattern claims, while conceptual, background, and industry sources informed contextualisation and the propositions in §5.4.

4.7. Methodological Limitations

Three constraints shape the interpretation of findings and are addressed more fully in §7.1: (a) screening was conducted by a single reviewer; (b) the search was restricted to IEEE Xplore and Scopus, both of which under-index educational research from the Global South and from non-English-language scholarship; and (c) the search string is technology- rather than equity-targeted, meaning that equity-focused literature outside the technology-enhanced learning core is not represented in the corpus.

These constraints calibrate the review's claims: findings should be read as what is visible within the technology-enhanced learning literature as conventionally indexed, rather than as a comprehensive account of equity in metaverse-related education. Notably, where equity gaps are visible even within this narrowly-indexed and technology-focused corpus, the implications can be argued to be conservative:

a more inclusive search across regional, equity-focused, and non-English databases would in all likelihood deepen rather than contradict the patterns reported here.

5. Results

The corpus comprised 79 records at the PRISMA inclusion stage (**Figure 1**). During analytical coding, two records were identified as duplicate publications and consolidated, and one editorial (Kirschner, 2002) was removed as inconsistent with the stated exclusion criteria (**Table 2**, Study Design row), yielding 76 unique sources for synthesis. Of these, 28 (36.8%) reported empirical fieldwork; the remaining 48 (63.2%) were systematic reviews, meta-analyses, conceptual or theoretical works, background or foundational works, or policy/industry documents. Source types are detailed in Appendix A. Distributions across the four coding variables are reported in the subsections that follow and summarised in **Table 4**. The complete corpus listing with per-source codings is provided in Appendix A; **Tables 4–7** below report aggregated patterns.

Table 4. Distribution of the Analytical Corpus Across Coding Variables (n = 76)

Variable	Category	n (%)
Geographic context	Global North	18 (23.4%)
	Global South	10 (13.0%)
	N/A (non-empirical)	48 (63.2%)
Equity engagement	Central	0 (0.0%)
	Secondary	5 (6.6%)
	Mentioned	15 (19.7%)
	Absent	56 (73.7%)
Period of publication	1981–1999	4 (5.2%)
	2000–2009	10 (13.0%)
	2010–2019	32 (41.6%)
	2020–2023	27 (35.1%)
	2024+	4 (5.2%)
Population resource context	Well-resourced	14 (18.2%)
	Under-resourced	6 (7.8%)
	Mixed	3 (3.9%)
	Not Specified	3 (3.9%)
	N/A (non-empirical)	50 (65.8%)

5.1. RQ1: Engagement with Equity Across Four Decades

Equity engagement was sparse across the corpus and emerged late. No source in the 76-source analytical corpus engaged equity as its central concern (0/76, 0.0%). Five sources (6.6%) engaged equity at a substantive level (Secondary). Fifteen sources (19.7%) referenced equity briefly without analytic engagement (Mentioned).

The largest category was Absent: 56 sources (73.7%) made no engagement with equity at any level. Across four decades of technology-enhanced learning research (1981–2024) as represented in the searched databases, no work emerged in which equity was the primary lens of analysis.

Engagement with equity is unevenly distributed across the period. The temporal pattern is reported in **Table 5**.

Table 5. Equity Engagement by Period of Publication (n = 76)

Period	Central	Secondary	Mentioned	Absent	Engaged (n, %)	Total
1981–1999	0	0	0	4	0 (0.0%)	4
2000–2009	0	0	0	10	0 (0.0%)	10
2010–2019	0	2	5	25	7 (21.9%)	32
2020–2023	0	3	8	16	11 (40.7%)	27
2024+	0	0	2	2	2 (50.0%)	4
Total	0	5	15	57	20 (26.3%)	77

Equity engagement was wholly absent before 2010 (0/13 records published in 1981–2009 engaged equity at any level). Engagement entered the literature in the 2010s at low intensity: 7 of 32 records (21.9%) published in 2010–2019 engaged equity in some form, and the two Secondary-level engagers from this decade [41,42] were both empirical studies of e-learning or MOOC adoption in under-resourced Global South contexts (Pakistan and Libya respectively). The pandemic period 2020–2023 produced a marked shift, with 11 of 27 records (40.7%) engaging equity, including three Secondary-level engagers [43–45]. The 2024+ bin (n = 4) shows continued engagement at the Mentioned level (2/4), but the cell is too small to support claims about post-pandemic trajectory.

This temporal pattern carries an important interpretive implication. The two routes by which equity has entered the corpus are distinct: empirical work from under-resourced Global South contexts in the 2010s, and conceptual reflection from the pandemic era in the 2020s. Equity engagement has therefore been catalysed either by direct empirical encounter with under-resourced settings, or by the global disruption of educational continuity. Neither route is structurally tied to the modality of technology being studied; both are tied to the contexts in which the work is being conducted. In the absence of either catalyst, equity does not appear to enter the technology-enhanced learning conversation through internal disciplinary momentum.

5.2. RQ2: Documented Barriers and Their Projected Behaviour in Metaverse Contexts

Among the 28 empirical sources in the corpus, none of the 14 studies of well-resourced populations engaged equity at any level (0/14 = 0.0%; all coded Absent). Among the 6 studies of under-resourced populations, 4 (66.7%) engaged equity (2 Secondary, 2 Mentioned). The corpus thus demonstrates that equity engagement tracks the resource context of the population studied, not the technological modality being studied (**Table 6**). We infer from this pattern that equity barriers become visible to researchers when they confront them directly in fieldwork, and remain invisible when they do not. The implication for metaverse-in-education research, which is being produced predominantly from well-resourced contexts, is that the literature has

not developed the empirical disposition to recognise equity barriers in environments where they are most likely to occur.

Table 6. Equity Engagement by Population Resource Context (Empirical Sources, n = 28)

Resource Context	Central	Secondary	Mentioned	Absent	Engaged (n)	Total
Well-resourced	0	0	0	14	0	14
Under-resourced	0	2	2	2	4	6
Mixed	0	0	2	1	2	3
Not Specified	0	0	0	3	0	3
Resource context not codable (n = 2)						2
Total empirical	0	2	4	20	6	28

Five categories of barriers are documented across the corpus and their projected behaviour in metaverse contexts is summarised in **Table 7**. For each, the synthesis assesses likely behaviour in metaverse environments — intensify, persist, or recede — based on documented mechanisms in the source literature.

Infrastructure barriers. Reliable internet connectivity, hardware availability, and electricity supply are persistently documented as preconditions for online learning, with differentiated outcomes across well- and under-resourced contexts [19,24,25,46]. Two of the corpus's five Secondary-level engagers — Khan et al. [41] on MOOC adoption in Pakistan and Rhema and Miliszewska [42] on engineering e-learning in Libya — centre infrastructure constraints in their analysis. Likely behaviour in metaverse contexts: intensification. Bandwidth, compute, and head-mounted display requirements raise the access threshold above the already-uneven baseline of two-dimensional online learning.

Educator preparedness barriers. Educator capacity to design and facilitate technology-enhanced instruction is documented across all three modalities as a determinant of effectiveness [25,44]. The pandemic-period sources in particular foreground rapid pivots that overran existing educator preparation. Likely behaviour: intensification. Three-dimensional, avatar-mediated environments require pedagogical competencies that current teacher-education programmes rarely address.

Data privacy and governance barriers. Concerns about learner data collection and storage are documented across the corpus and are discussed with growing intensity in metaverse-related literature [2,47,48]. Likely behaviour: intensification. The persistent and biometric-rich nature of immersive data capture raises governance demands above those associated with two-dimensional platforms.

Social presence and engagement barriers. Reduced social presence, isolation, and weakened community in online learning are well documented [24,49]. Likely behaviour: conditional recession. Immersive co-presence may address one of the most consistently reported limitations of two-dimensional online learning, but only when accompanied by intentional pedagogical design; the architectural affordance does not guarantee the pedagogical outcome.

Cost and platform sovereignty barriers. The cost barrier is variable across the corpus; the platform sovereignty issue — institutional dependence on commercial platforms — is more visible in the metaverse-related literature than in earlier modalities [2,8]. Likely behaviour: intensification. Commercial platform dependence

and hardware costs structurally exceed those of two-dimensional online learning, and many existing institutional online platforms are open or non-commercial in ways the predominant immersive ecosystem currently is not.

Table 7. Documented Barriers, Mechanisms, and Projected Behaviour in Metaverse Contexts

Barrier Category	Mechanism Documented in Corpus	Projected Behaviour in Metaverse Contexts	Confidence in Projection
Infrastructure	Differential connectivity, device availability, and electricity supply produce uneven access; under-resourced settings show lower completion and engagement.	Intensification. Bandwidth, compute, and head-mounted display requirements raise the threshold.	High. Mechanism is structural; metaverse access requirements unambiguously exceed those of online learning.
Educator preparedness	Educator capacity to design and facilitate technology-enhanced instruction is a determinant of effectiveness; pandemic-era pivots exposed preparation gaps.	Intensification. Three-dimensional pedagogy is poorly represented in current teacher-education curricula.	High. Pedagogical novelty of immersive environments documented across recent literature.
Data privacy and governance	Learner data collection and storage are recurring concerns; emerging literature foregrounds governance gaps.	Intensification. Persistent and biometric-rich immersive data capture raises governance demands.	Medium-High. Direction is consistent across literature; magnitude is platform- and jurisdiction-dependent.
Social presence and engagement	Reduced social presence and isolation in two-dimensional online learning; diminished community among distance learners.	Conditional recession. Co-presence may resolve presence deficits when supported by intentional design.	Medium. Affordance is real but outcome is contingent on pedagogy and access.
Cost and platform sovereignty	Hardware and platform cost variability; commercial platform dependence is more salient in metaverse than in online learning.	Intensification. Hardware costs and commercial platform dependence structurally exceed those of online learning.	Medium-High. Hardware cost trajectory is the primary uncertainty.

5.3. RQ3: Transferability of Documented Responses

The transferability question presupposes a body of evidenced responses to documented equity barriers. The corpus contains relatively little such evidence. Of the 28 empirical sources, none reports a study in which an equity-oriented intervention was tested for effectiveness; equity, where it appears, is identified as a contextual challenge rather than addressed through experimental or quasi-experimental design. The corpus therefore yields candidate responses through the mechanisms and affordances documented in implementation studies, rather than through evidenced effectiveness comparisons. This is itself a finding: the technology-enhanced learning literature, as conventionally indexed in IEEE Xplore and Scopus, does not appear to have produced empirical work directly testing whether identified equity barriers can be remediated by deliberate design. The implication for the metaverse field is that responses transferred from earlier modalities are inherited as candidate strategies, not as evidence-based remedies.

A further gap is noted: the corpus contains no studies on the socio-technical engineering challenges of building equitable metaverse platforms. A systematic mapping study published after the June 2024 search cutoff — Di Dario, Palomba, and Gravino (2024), “Another brick in the wall: A systematic mapping study toward defining metaverse engineering through socio-technical issues” (ACM Computing Surveys) — provides the most comprehensive post-search evidence for this gap, cataloguing 19 social and 18 technical issues affecting metaverse development and explicitly foregrounding fairness, equity, and sustainability as engineering objectives. Its emergence after the search window is consistent with the pattern identified in this corpus: socio-technical and equity-centred metaverse research is nascent and growing rapidly. The propositions in §5.4 reflect the absence of such evidence within the corpus; future replication should include socio-technical engineering databases. Five candidate response categories can be extracted from the implementation-focused literature in the corpus.

Mobile-first and low-bandwidth design. Studies of e-learning and MOOC adoption in under-resourced contexts [41,42,46] consistently identify mobile-accessible, low-bandwidth-tolerant design as a precondition for adoption. Transferability to metaverse environments is structurally constrained: high-fidelity immersive experiences are bandwidth-intensive and cannot be straightforwardly down-converted to mobile or low-bandwidth delivery without losing the affordances that distinguish them from earlier modalities. Mixed-fidelity design — pairing low-bandwidth desktop or two-dimensional fallbacks with high-fidelity immersive options — is a candidate but not yet evidenced strategy.

Asynchronous-first delivery as a fallback. The online learning literature consistently shows asynchronous delivery accommodating intermittent connectivity, varied schedules, and distributed institutional contexts [22,23]. Transferability: partial. Metaverse co-presence is structurally synchronous, and asynchronous metaverse interaction is a less-developed design pattern. Maintaining two-dimensional asynchronous channels alongside synchronous immersive sessions is the most plausible adaptation.

Educator capacity-building. Pandemic-period sources foreground educator preparation gaps and the need for sustained training [25,44]. Transferability: high. Educator capacity-building is platform-agnostic and the most directly transferable response in the corpus, though the content of training would need to be substantially rebuilt for three-dimensional and avatar-mediated pedagogies.

Institutional infrastructure investment. Studies from Global South contexts foreground institutional and policy investment as preconditions for technology-enhanced learning [25,46]. Transferability: high in principle, but at higher cost. Institutional metaverse provisioning involves device fleets, software licensing, technical staff, and sustained infrastructure spend that exceed those of two-dimensional online learning.

Open and institutionally-hosted platform alternatives. The earlier online learning literature includes substantial work on open educational resources and institutionally hosted learning management systems. The corpus contains less direct treatment of open or institutional alternatives in the immersive space. Transferability: low without sustained development effort. Open-source metaverse platforms exist but are not at present dominant in educational deployment.

Read collectively, the responses available for transfer are concentrated in pedagogical and institutional categories rather than in technical-design categories. The implication is that equitable metaverse-based learning is, on present evidence,

more achievable through institutional and pedagogical investment than through technical design alone.

5.4. RQ4: Conditions for Equity-Reducing Metaverse-Based Learning

Synthesising findings across RQ1–RQ3, the corpus permits a conditional answer to the review's central question. Metaverse-based learning may plausibly reduce rather than reproduce educational inequities under specified conditions, none of which is automatic and several of which the current trajectory of metaverse-education research does not support. These conditions are advanced as testable propositions for empirical investigation, not as conclusions from the present synthesis.

Proposition 1 (Empirical disposition). Metaverse-based learning will reduce educational inequities only where the research and design communities studying it develop sustained empirical engagement with under-resourced populations. This is a testable proposition, not a conclusion. The corpus demonstrates that equity engagement tracks the resource context of the population studied: 0/14 well-resourced empirical studies engaged equity, against 4/6 under-resourced studies. We infer from this pattern that a metaverse-in-education literature produced overwhelmingly from well-resourced settings is structurally unlikely to surface equity dynamics unless the research community deliberately seeks out under-resourced study populations.

Proposition 2 (Mixed-fidelity access). Equitable metaverse-based learning requires deliberate provision of low-bandwidth and non-immersive access pathways alongside high-fidelity immersive experiences. The infrastructure barriers documented in the corpus do not recede in metaverse contexts; they intensify. Mixed-fidelity design is the most plausible architectural response, but is not yet an evidenced strategy.

Proposition 3 (Educator preparation). Equitable metaverse-based learning depends on educator preparedness programmes specifically developed for three-dimensional and avatar-mediated pedagogies. The pandemic-period evidence of preparation gaps in two-dimensional online instruction predicts more severe gaps in immersive contexts in the absence of deliberate intervention.

Proposition 4 (Institutional and platform sovereignty). Equitable metaverse-based learning requires institutional infrastructure investment and platform options that are not exclusively commercial. The platform sovereignty barrier is more pronounced in metaverse contexts than in earlier digital modalities, and existing institutional online learning ecosystems do not have direct analogues in the predominant commercial metaverse platforms.

Proposition 5 (Governance frameworks). Equitable metaverse-based learning requires governance frameworks for learner data, identity representation, and platform access that have not been developed at scale for immersive educational contexts. The data and identity dimensions of metaverse environments exceed the governance challenges of earlier modalities.

These five conditions are mutually reinforcing. The absence of any one is likely to undermine the contribution of the others. The conditions also map onto distinct stakeholder groups — researchers, designers, educators, institutions, and policymakers — and their satisfaction therefore requires coordinated rather than sequential action across these groups.

6. Discussion

6.1. Four Decades of Evidence, Read Through an Equity Lens

The synthesis reported here positions the metaverse not as a technological

category that warrants a fresh equity analysis, but as the latest in a sequence of digital learning modalities whose equity dynamics have already been extensively documented. Read against the corpus, three findings frame what the evidence permits the field to claim about the educational metaverse.

First, the technology-enhanced learning literature, as represented in IEEE Xplore and Scopus across four decades (1981–2024), has not produced a body of work in which equity is centrally analysed — within the conventionally indexed, technology-targeted corpus searched here. No source engaged equity as its primary concern, and only 6.6% engaged it substantively. This is not a finding about the metaverse alone; it is a finding about the discipline within which metaverse-in-education research is being produced. The discipline has, by this measure, treated equity as a contextual variable rather than an analytical object across the entire history of digital learning research.

Second, equity engagement is a recent and largely pandemic-driven phenomenon. Equity is wholly absent from the literature before 2010 and only meaningfully present from 2020 onwards. The metaverse-in-education conversation has therefore arisen at a moment when the literature is, for the first time, beginning to engage equity at scale. This creates an opportunity that earlier waves of educational technology research did not have: the metaverse field is being built in a moment when the equity question is in active circulation rather than settled. Whether the field metabolises this opportunity is the open question.

Third, equity engagement in the corpus is contextually triggered rather than disciplinarily driven. It enters through pandemic-era reflection or through empirical work in under-resourced settings, and otherwise does not appear. For the metaverse field — which is currently produced predominantly from well-resourced settings and which, for the moment, remains in pre-pandemic-style growth — neither structural trigger is presently active. Equity engagement in metaverse-in-education research will therefore have to be deliberately introduced rather than passively inherited from the literature it draws on.

6.2. Where the Metaverse Genuinely Differs

Two properties of metaverse environments are not reducible to earlier modalities and warrant analytic distinction. The first is co-presence: the capacity for synchronous, embodied interaction within shared persistent space. Where the social presence deficits of two-dimensional online learning have been a consistent finding [24,49], co-presence is the affordance most plausibly positioned to address that deficit. This affordance is at the centre of the metaverse-as-equity argument.

The second is experiential affordance: the capacity for direct manipulation of simulated objects, environments, and procedures. In contexts where physical laboratory infrastructure, expert practitioners, or specialised equipment are unavailable — circumstances disproportionately affecting under-resourced educational settings — high-fidelity simulation may provide forms of experiential learning that are otherwise inaccessible [50,51].

Both properties hold genuine equity-relevant promise. Both are also conditional on hardware, bandwidth, platform access, and pedagogical design — the same conditions under which earlier digital learning has variably succeeded and failed. The corpus indicates that none of these conditions is automatic and that, on the evidence of the past four decades, none is currently being met by default. Treating co-presence and experiential affordance as automatic equity-enhancers risks repeating the analytic error that previous educational technology cycles have made: assuming that an

affordance present in the technology will be realised in deployment regardless of the contextual conditions of that deployment.

6.3. The Conservative Case for Cautious Optimism

A balanced reading of the evidence supports neither uncritical advocacy nor categorical skepticism. The corpus indicates that equity-relevant design and pedagogical responses developed for online and gamified learning — educator capacity-building, institutional infrastructure investment, mixed-fidelity access, asynchronous fallbacks — are in principle transferable to metaverse contexts. Where these responses are integrated into immersive learning design from the outset, plausible pathways to equity-enhancing metaverse-based learning exist.

Where they are not — where metaverse design proceeds as if the affordances themselves are sufficient — the reproducibility of earlier digital divides should be considered the default expectation. The metaverse is not an exception to the patterns documented in technology-enhanced learning research; it is the most recent test of whether those patterns can be broken. The evidence reviewed here does not predict the outcome of that test. It identifies, with reasonable confidence, the conditions under which the test is likely to be passed.

6.4. Implications

For educators and instructional designers, the evidence indicates that metaverse-based learning requires equity-led rather than affordance-led design. Decisions about platform, hardware fidelity, and pedagogical structure should be evaluated against documented access and engagement risks before being evaluated against learning-outcome potential.

For institutions, the prerequisites for equitable metaverse-based learning include sustained infrastructure investment, educator capacity-building, and platform sovereignty considerations that the predominantly commercial current metaverse ecosystem does not currently support.

For policymakers, the metaverse extends rather than transcends the policy questions that online learning and educational technology adoption have raised over four decades. Data governance, platform regulation, and equitable access programmes should be regarded as preconditions rather than peripheral concerns.

For researchers, the priority is empirical work that engages directly with equity-relevant variables: studies disaggregated by resource context, longitudinal designs, and comparative work across modalities and infrastructures. The propositions developed in §5.4 are advanced as candidates for empirical testing, not as conclusions. The disciplinary pattern surfaced by this review — that equity engagement is contextually triggered rather than structurally embedded — applies as a caution to the next phase of metaverse-in-education research.

7. Conclusion

This systematic review has synthesised four decades of evidence on online learning, gamified education, and metaverse-related research (1981–2024) to address a focused question: will the educational metaverse reproduce or reduce educational inequities? The answer the evidence permits is conditional. The architectural properties of metaverse environments hold genuine equity-relevant potential, particularly through co-presence and experiential affordance. The conditions under which this potential is realised are precisely those that earlier digital learning research has repeatedly identified as preconditions for equitable technology-enhanced learning:

deliberate empirical engagement with under-resourced populations, mixed-fidelity access pathways, educator preparation, institutional and platform sovereignty, and governance frameworks. Where these conditions are met, metaverse-based learning may genuinely reduce educational inequities. Where they are not — and the corpus shows that they are not currently met by default — the reproduction of earlier digital divides should be the expected outcome.

The contribution of this review is to reframe the speculative equity claims that currently characterise the metaverse-in-education discourse as testable empirical propositions, and to ground the next phase of empirical research in the accumulated evidence of preceding modalities. The headline finding is sobering: across four decades of research as conventionally indexed, no source centred equity as its primary concern (0/76). This finding reflects patterns within a single-reviewer-coded, technology-targeted corpus restricted to two databases and should be read as an indicative pattern warranting further investigation. Whether the metaverse-in-education literature will be the first to centre equity is a choice the field has not yet made.

7.1. Limitations and Future Research

This review has six principal limitations.

First, all screening and analytical coding was conducted by a single reviewer without inter-rater reliability assessment. This is a significant constraint, particularly for the equity-engagement coding, which is the review's most consequential and interpretive coding dimension. Without a second coder, the confidence in individual coding assignments is limited to the explicit rubric and per-source confidence ratings in Appendix A. Readers should treat the precise distribution of equity-engagement codes as indicative. Multi-reviewer coding with formal reliability statistics is recommended for any replication.

Second, the search was restricted to IEEE Xplore and Scopus, both of which under-index educational research from the Global South and from non-English-language scholarship. ERIC, AJOL (African Journals Online), and SciELO are obvious candidates for inclusion in extended versions of this review. The likely effect of including these databases would be to increase the visibility of equity-engaged and Global-South-situated work, which would strengthen rather than contradict the central findings of this synthesis.

Third, the search string is technology-targeted rather than equity-targeted. Equity-focused educational research that does not foreground metaverse, gamification, or online learning terminology will not have been retrieved. The corpus is therefore best read as the equity content within the technology-enhanced learning literature, not as the totality of equity-relevant work that bears on metaverse-based education.

Fourth, 12 of 76 codings (15.8%) were assigned Low confidence due to incomplete information in source abstracts. Confidence ratings for individual codings are reported in Appendix A. The headline patterns concern absences (no Central engagement; no equity engagement before 2010, 0/13; no engagement in well-resourced empirical studies) and are robust to changes in individual Low-confidence codings, since reassigning a Low-confidence Absent code to Mentioned or Secondary would marginally adjust but not overturn the patterns reported. Fifth, the search was conducted in June 2024. In a rapidly evolving field, a gap is a meaningful limitation on corpus currency. An updated search covering June 2024 to the present is recommended before any replication or extension. Sixth, the equity-engagement coding captures depth of engagement but does not disaggregate by type of equity

concern (e.g., infrastructure equity, disability and accessibility, gender equity, data privacy and biometrics). This limits the specificity of the analysis for metaverse-specific equity concerns. A secondary equity-type coding dimension is recommended for future replications.

Future research should accordingly: (a) replicate this synthesis with multi-reviewer coding, an updated search, and a broader database set including ERIC, AJOL, and SciELO; (b) test the five conditional propositions in §5.4 through purpose-designed empirical studies — for example, comparing equity engagement in metaverse studies from well-resourced versus under-resourced settings (Proposition 1), evaluating mixed-fidelity access designs against equity outcome measures (Proposition 2), assessing educator preparation programmes for three-dimensional pedagogy (Proposition 3), comparing institutionally-hosted versus commercial metaverse platforms on access equity (Proposition 4), and auditing learner data governance frameworks against established equity standards (Proposition 5); (c) develop longitudinal designs distinguishing novelty effects from sustained equity-relevant outcomes; (d) add a secondary equity-type coding dimension; and (e) advance comparative work across modalities and differently-resourced settings.

Author contributions: The author (A.G.) was solely responsible for the conceptualization, methodology, formal analysis, investigation, data curation, and writing—original draft preparation, review, and editing of this manuscript. The author has read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Ethical statement: This research did not require ethical approval since it did not involve direct participation of human or animal subjects. An ethical waiver was acquired for this study.

Acknowledgments: Not applicable.

Conflicts of interest: The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Bell MW. Toward a definition of virtual worlds. *Journal of Virtual Worlds Research*. 2008, 1(1): 1–5. <http://doi.org/10.4101/jvwr.v1i1.283>.
2. Dwivedi YK, Hughes L, Baabdullah AM, et al. Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*. 2022, 66: 102542. <http://doi.org/10.1016/j.ijinfomgt.2022.102542>.
3. Mystakidis S. Metaverse. *Encyclopedia*. 2022, 2(1): 486–497. <http://doi.org/10.3390/encyclopedia2010031>.
4. Zhang X, Chen Y, Hu L, et al. The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Frontiers in Psychology*. 2022, 13: 1016300. <http://doi.org/10.3389/fpsyg.2022.1016300>.
5. Hodges C, Moore S, Locke B, et al. The difference between emergency remote teaching and online learning. *EDUCAUSE Review*. 2020, 27 March. Available online: <https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning> (accessed on 21 May 2026).
6. Chen L, et al. Enhancing EFL learning with chatbots. *International Journal of AI in Education*. 2023, 15: 300–310.
7. De Felice S, Hamilton AFC, Ponari M, et al. Learning from others is good, with others is better: The role of social interaction in human acquisition of new knowledge. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2023, 378(1870): 20210357. <http://doi.org/10.1098/rstb.2021.0357>.
8. Lin H, Wan S, Gan W, et al. Metaverse in education: Vision, opportunities, and challenges. In: *Proceedings of the 2022 IEEE International Conference on Big Data (Big Data)*; 17–20 December 2022; Osaka, Japan. IEEE; 2022. pp. 2857–2866. <http://>

- doi.org/10.1109/BigData55660.2022.10021004.
9. Selwyn N. Education and technology: Key issues and debates, 2nd ed. Bloomsbury Academic; 2016.
10. Warschauer M. Technology and social inclusion: Rethinking the digital divide. MIT Press; 2004. <http://doi.org/10.7551/mitpress/6699.001.0001>.
11. Stephenson N. Snow crash. Bantam Books; 1992.
12. DiMaggio P, Hargittai E. From the digital divide to digital inequality: Studying internet use as penetration increases. Center for Arts and Cultural Policy Studies, Princeton University; 2001. Working Paper No. 15.
13. Norris P. Digital divide: Civic engagement, information poverty, and the internet worldwide. Cambridge University Press; 2001. <http://doi.org/10.1017/CBO9781139164887>.
14. Hargittai E. Second-level digital divide: Differences in people's online skills. First Monday. 2002, 7(4). <http://doi.org/10.5210/fm.v7i4.942>.
15. van Dijk JAGM. The deepening divide: Inequality in the information society. SAGE; 2005. <http://doi.org/10.4135/9781452229812>.
16. Ragnedda M. The third digital divide: A Weberian approach to digital inequalities. Routledge; 2017. <http://doi.org/10.4324/9781315606002>.
17. van Deursen AJAM, Helsper EJ. The third-level digital divide: Who benefits most from being online? In: Robinson L, Cotten SR, Schulz J (editors). Communication and information technologies annual: Digital distinctions and inequalities. Emerald; 2015. pp. 29–52. <http://doi.org/10.1108/S2050-206020150000010002>.
18. Mitra A. Categories of computer use and their relationships with attitudes toward computers. Journal of Research on Computing in Education. 1998, 30(3): 281–294. <http://doi.org/10.1080/08886504.1998.10782227>.
19. Paris PG. E-learning: A study on secondary students' attitudes towards online web-assisted learning. International Education Journal. 2004, 5(1): 98–112.
20. Gray E, Czerniewicz L. Access to learning resources in post-apartheid South Africa. In: Karaganis J (editor). Shadow libraries: Access to knowledge in global higher education. MIT Press; 2018. pp. 107–158. <http://doi.org/10.7551/mitpress/11339.003.0006>.
21. Reich J. Failure to disrupt: Why technology alone can't transform education. Harvard University Press; 2020.
22. Means B, Toyama Y, Murphy R, et al. Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies. U.S. Department of Education, Office of Planning, Evaluation, and Policy Development; 2009.
23. Panigrahi R, Srivastava PR, Sharma D. Online learning: Adoption, continuance, and learning outcome - A review of literature. International Journal of Information Management. 2018, 43: 1–14. <http://doi.org/10.1016/j.ijinfomgt.2018.05.005>.
24. Almahasees Z, Mohsen K, Amin MO. Faculty's and students' perceptions of online learning during COVID-19. Frontiers in Education. 2021, 6: 638470. <http://doi.org/10.3389/feduc.2021.638470>.
25. Yusuf BN. Are we prepared enough? A case study of challenges in online learning in a private higher learning institution during the COVID-19 outbreaks. Advances in Social Sciences Research Journal. 2020, 7(5): 205–212. <http://doi.org/10.14738/assrj.75.8211>.
26. Czerniewicz L, Agherdien N, Badenhorst J, et al. A wake-up call: Equity, inequality and Covid-19 emergency remote teaching and learning. Postdigital Science and Education. 2020, 2(3): 946–967. <http://doi.org/10.1007/s42438-020-00187-4>.
27. Williamson B, Eynon R, Potter J. Pandemic politics, pedagogies and practices: Digital technologies and distance education during the coronavirus emergency. Learning, Media and Technology. 2020, 45(2): 107–114. <http://doi.org/10.1080/17439884.2020.1761641>.
28. Dicheva D, Dichev C, Agre G, et al. Gamification in education: A systematic mapping study. Educational Technology & Society. 2015, 18(3): 75–88.
29. Hamari J, Koivisto J, Sarsa H. Does gamification work? A literature review of empirical studies on gamification. In: Proceedings of the 47th Hawaii International Conference on System Sciences; 6–9 January 2014; Waikoloa, HI, USA. IEEE; 2014. pp. 3025–3034. <http://doi.org/10.1109/HICSS.2014.377>.
30. Kapp KM. The gamification of learning and instruction: Game-based methods and strategies for training and education. Pfeiffer; 2012.
31. Koivisto J, Hamari J. The rise of motivational information systems: A review of gamification research. International Journal of Information Management. 2019, 45: 191–210. <http://doi.org/10.1016/j.ijinfomgt.2018.10.013>.

32. Landers RN, Armstrong MB, Collmus AB. How to use game elements to enhance learning: Applications of the theory of gamified learning. In: Ma M, Oikonomou A, Jain LC (editors). *Serious games and edutainment applications*. Springer; 2017. Volume 2, pp. 457–483. http://doi.org/10.1007/978-3-319-51645-5_21.
33. Jandrić P, McLaren P. From learning loss to learning opportunity. *Educational Philosophy and Theory*. 2021, 56(1): 1–9. <http://doi.org/10.1080/00131857.2021.2010544>.
34. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*. 2021, 372: n71. <http://doi.org/10.1136/bmj.n71>.
35. Gough D, Oliver S, Thomas J. *An introduction to systematic reviews*, 2nd ed. SAGE; 2017.
36. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*. 1989, 13(3): 319–340. <http://doi.org/10.2307/249008>.
37. Malone TW. Toward a theory of intrinsically motivating instruction. *Cognitive Science*. 1981, 5(4): 333–369. http://doi.org/10.1207/s15516709cog0504_2.
38. Prensky M. Digital natives, digital immigrants: Part 1. *On the Horizon*. 2001, 9(5): 1–6. <http://doi.org/10.1108/10748120110424816>.
39. Prensky M. Digital natives, digital immigrants, part 2: Do they really think differently? *On the Horizon*. 2001, 9(6): 1–6. <http://doi.org/10.1108/10748120110424843>.
40. Thomas J, Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology*. 2008, 8: 45. <http://doi.org/10.1186/1471-2288-8-45>.
41. Khan IU, Hameed Z, Yu Y, et al. Predicting the acceptance of MOOCs in a developing country: Application of task-technology fit model, social motivation, and self-determination theory. *Telematics and Informatics*. 2018, 35(4): 964–978. <http://doi.org/10.1016/j.tele.2017.09.009>.
42. Rhema A, Miliszewska I. Analysis of student attitudes towards e-learning: The case of engineering students in Libya. *Issues in Informing Science and Information Technology*. 2014, 11: 169–190. <http://doi.org/10.28945/1987>.
43. Chung H, Lippe T. Flexible working, work-life balance, and gender equality: Introduction. *Social Indicators Research*. 2020, 151: 1–17. <http://doi.org/10.1007/s11205-018-2025-x>.
44. Ferri F, Grifoni P, Guzzo T. Online learning and emergency remote teaching: Opportunities and challenges in emergency situations. *Societies*. 2020, 10(4): 86. <http://doi.org/10.3390/soc10040086>.
45. Jandrić P, Hayes D, Truelove I, et al. Teaching in the age of Covid-19 - The new normal. *Postdigital Science and Education*. 2022, 4(3): 877–1015. <http://doi.org/10.1007/s42438-022-00332-1>.
46. Asabere NY, Enguah SE. Integration of expert systems in mobile learning. *International Journal of Information and Communication Technology Research*. 2012, 2(1): 55–61.
47. Kaddoura S, Al Hussein F. The rising trend of metaverse in education: Challenges, opportunities, and ethical considerations. *PeerJ Computer Science*. 2023, 9: e1252. <http://doi.org/10.7717/peerj-cs.1252>.
48. Onu P, Mbohwa C, Pradhan A. Internet of Production: Unleashing the full potential of Industry 4.0 - A comprehensive review of trends, drivers, and challenges. *Procedia Computer Science*. 2024, 232: 2049–2056. <http://doi.org/10.1016/j.procs.2024.02.027>.
49. Lee H, Woo D, Yu S. Virtual reality metaverse system supplementing remote education methods: Based on aircraft maintenance simulation. *Applied Sciences*. 2022, 12(5): 2667. <http://doi.org/10.3390/app12052667>.
50. Dalgarno B, Lee MJW. What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology*. 2010, 41(1): 10–32. <http://doi.org/10.1111/j.1467-8535.2009.01038.x>.
51. Getchell K, Oliver I, Miller A, et al. Metaverses as a platform for game-based learning. In: *Proceedings of the 24th IEEE International Conference on Advanced Information Networking and Applications*; 20–23 April 2010; Perth, Australia. IEEE; 2010. pp. 1195–1202. <http://doi.org/10.1109/AINA.2010.125>.

Appendix A. Sources in the Analytical Corpus (n = 76)

This appendix lists all 76 sources in the analytical corpus, sorted alphabetically by first author, with each source's coding on the four variables described in §4.5: Geographic Context (Geo), Equity Engagement (Eq), Period of Publication (Per), and Population Resource Context (Res). Codings reflect the rubric in **Table 3** and are accompanied by a confidence rating (Conf): H = High, M = Medium, L = Low. Sources marked with an asterisk (*) are also cited in the prose of the manuscript and therefore appear in the main References section in full APA 7 format. Each source is additionally classified by Source Type (ST): (1) Peer-reviewed empirical study (default); (2) Systematic review or meta-analysis; (3) Conceptual or theoretical work; (4) Policy, industry, or grey literature document; (5) Background or foundational work. Sources in categories (4) and (5) that are retained are accompanied by a one-sentence relevance justification in brackets. Where a coding decision requires rationale, this is also noted in brackets.

Abbreviations: Geo: GN = Global North; GS = Global South; Mx = Mixed; NS = Not Specified; N/A = non-empirical work. Eq: C = Central; S = Secondary; M = Mentioned; A = Absent. Per: bins are 1981–1999, 2000–2009, 2010–2019, 2020–2023, and 2024+ (where the 2024+ bin contains four works retrieved through citation tracing after the original search end date and retained where they met eligibility criteria, see §4.2). Res: WR = Well-resourced; UR = Under-resourced; Mx = Mixed; NS = Not Specified; N/A = non-empirical.

Source	Geo	Eq	Per	Res	Conf
Al Shlowiy, A. (2023). Language learners' disengagement in e-learning during COVID-19. <i>World Journal of English Language</i> , 13.	GN	M	2020–2023	Mx	M
Alam, A., & Mohanty, A. (2023). Educational technology: Exploring the convergence. <i>Cogent Engineering</i> , 10, 2283282.	N/A	M	2020–2023	N/A	M
Alghamdi, N. S., & Alghamdi, S. M. (2022). The role of digital technology in curbing COVID-19. <i>IJERPH</i> , 19(14), 8287.	N/A	A	2020–2023	N/A	M
* Almahasees, Z., Mohsen, K., & Amin, M. O. (2021). Faculty's and students' perceptions of online learning during COVID-19. <i>Frontiers in Education</i> , 6, 638470.	GS	M	2020–2023	UR	M
Anshari, M., et al. (2017). Smartphones usage in the classrooms: Learning aid or interference? <i>Education and Information Technologies</i> , 22.	GS	A	2010–2019	WR	L
* Asabere, N. Y., & Enguah, S. E. (2012). Integration of expert systems in mobile learning. <i>IJICTR</i> , 2, 55–61.	GS	M	2010–2019	UR	H
Barata, G., et al. (2013). Improving participation and learning with gamification. <i>ACM Conference Proceedings</i> .	GN	A	2010–2019	WR	M
Brill, J., & Park, Y. (2008). Facilitating engaged learning in the interaction age. <i>IJTLHE</i> , 20(1), 70–78.	N/A	A	2000–2009	N/A	M
Bulger, M., Mayer, R., & Almeroth, K. (2006). Engaged by design: Using simulations to promote active learning.	GN	A	2000–2009	WR	M
* Chen, L., et al. (2023). Enhancing EFL learning with chatbots. <i>International Journal of AI in Education</i> , 15, 300–310.	GN	A	2020–2023	NS	L
* Chung, H., & Lippe, T. (2020). Flexible working, work–life balance, and gender equality. <i>Social Indicators Research</i> , 151.	N/A	S	2020–2023	N/A	M

Continuation Table:

Source	Geo	Eq	Per	Res	Conf
Crouch, C., et al. (2007). Peer instruction: Engaging students one-on-one, all at once.	GN	A	2000–2009	WR	M
* Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? BJET, 41.	N/A	A	2010–2019	N/A	H
* De Felice, S., et al. (2023). Learning from others is good, with others is better. Phil. Trans. R. Soc. B, 378.	N/A	A	2020–2023	N/A	L
De Freitas, S. (2018). Are games effective learning tools? A review. Educational Technology and Society, 21, 74–84.	N/A	A	2010–2019	N/A	H
* Dicheva, D., et al. (2015). Gamification in education: A systematic mapping study. Educational Technology and Society, 18, 75–88.	N/A	A	2010–2019	N/A	M
* Dwivedi, Y. K., et al. (2022). Metaverse beyond the hype. International Journal of Information Management, 66, 102542.	N/A	M	2020–2023	N/A	M
Dyulicheva, Y., & Glazieva, A. (2021). Game-based learning with AI and immersive technologies: An overview.	N/A	A	2020–2023	N/A	M
Epic Games. (2021). Unreal engine and the metaverse. [Industry document]. [ST:4. Retained: provides technical context on metaverse platform architecture relevant to infrastructure barrier analysis in §5.2.]	N/A	A	2020–2023	N/A	H
Facebook. (2021). Building the metaverse responsibly. [Industry document]. [ST:4. Retained: documents platform governance commitments and equity framing from a major metaverse platform developer, directly informing §5.2 cost and platform sovereignty discussion.]	N/A	M	2020–2023	N/A	M
* Ferri, F., Grifoni, P., & Guzzo, T. (2020). Online learning and emergency remote teaching. Societies, 10(4), 86.	N/A	S	2020–2023	N/A	M
* Getchell, K., et al. (2010). Metaverses as a platform for game-based learning. AINA Proceedings.	N/A	A	2010–2019	N/A	L
Greeno, J. G. (1998). The situativity of knowing, learning, and research. American Psychologist, 53(1).	N/A	A	1981–1999	N/A	H
Hai-Jew, S. (2020). Evaluating MS Teams for teaching and learning. C2C Digital Magazine, 1(13), 7. [ST:4. Retained: documents practitioner evaluation of a technology-enhanced learning platform in an emergency remote teaching context, relevant to §5.2 educator preparedness analysis. Conf=M reflects non-peer-reviewed source.]	N/A	A	2020–2023	N/A	M
* Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? — A literature review. HICSS.	N/A	A	2010–2019	N/A	H
Hew, K. F., & Cheung, W. S. (2014). Students' and instructors' use of MOOCs. Educational Research Review, 12.	GN	M	2010–2019	N/A	M
Hew, K. F., & Lo, C. K. (2020). Comparing video styles and study strategies during video-recorded lectures. Interactive Learning Environments, 28.	GN	A	2020–2023	WR	L

Continuation Table:

Source	Geo	Eq	Per	Res	Conf
* Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning.	N/A	M	2020–2023	N/A	H
Hung, D. W., Tan, S. C., & Koh, T. S. (2006). Engaged learning: Making learning an authentic experience.	N/A	A	2000–2009	N/A	M
Hwang, G.-J., & Wu, P.-H. (2012). Advancements and trends in digital game-based learning research 2001–2010. <i>BJET</i> , 43.	N/A	A	2010–2019	N/A	H
Jackson, E., & Jackson, H. (2024). Enhancing human knowledge and capabilities with AI tools for education. <i>Educational Challenges</i> .	N/A	M	2024+	N/A	L
Jagatheesaperumal, S., et al. (2024). Advancing education through extended reality and IoE-enabled metaverses. <i>IEEE TLT</i> .	N/A	M	2024+	N/A	M
* Jandrić, P., et al. (2022). Teaching in the age of Covid-19—The new normal. <i>Postdigital Science and Education</i> , 4(3).	N/A	S	2020–2023	N/A	M
Johnson, D., et al. (2016). Gamification for health and wellbeing: A systematic review. <i>Internet Interventions</i> , 6. [ST:2. Retained: gamification mechanisms documented in health contexts are directly transferable to the gamified learning analysis; equity implications of differential engagement outcomes are noted in §2.3.]	N/A	A	2010–2019	N/A	H
* Kaddoura, S., & Al Husseiny, F. (2023). The rising trend of metaverse in education. <i>PeerJ Computer Science</i> , 9, e1252.	N/A	M	2020–2023	N/A	M
* Kapp, K. M. (2012). The gamification of learning and instruction. Pfeiffer.	N/A	A	2010–2019	N/A	H
Karlsson, L., & Shamoun, M. (2022). Virtual realities for remote working [Master's thesis, Linnaeus University]. [ST:4. Retained: indexed in Scopus; addresses VR in remote work/ learning contexts relevant to §5.3. Conf=L reflects grey literature source type.]	GN	A	2020–2023	WR	L
Kaur, N., Singh, V., Mahajan, N., & Garg, N. (2023). Game-based learning — Immersive teaching and learning platform through metaverse. <i>ICIPTM</i> .	N/A	A	2020–2023	N/A	L
* Khan, I. U., et al. (2018). Predicting the acceptance of MOOCs in a developing country. <i>Telematics and Informatics</i> , 35.	GS	S	2010–2019	UR	H
Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. <i>Internet and Higher Education</i> , 8.	N/A	A	2000–2009	N/A	H
* Koivisto, J., & Hamari, J. (2019). The rise of motivational information systems: A review of gamification research. <i>IJIM</i> , 45.	N/A	A	2010–2019	N/A	H
Landers, R. N., & Landers, A. K. (2015). An empirical test of the theory of gamified learning. <i>Simulation & Gaming</i> , 45.	GN	A	2010–2019	WR	M

Continuation Table:

Source	Geo	Eq	Per	Res	Conf
* Landers, R. N., Armstrong, M. B., & Collmus, A. B. (2017). How to use game elements to enhance learning.	N/A	A	2010–2019	N/A	H
* Lee, Y., Hwang, G., & Chen, P. (2022). Impacts of an AI-based chatbot on college students. <i>ETR&D</i> , 70, 1843–1865.	GN	A	2020–2023	WR	H
* Lee, H., Woo, D., & Yu, S. (2022). Virtual reality metaverse system supplementing remote education methods. <i>Applied Sciences</i> , 12(5).	GN	A	2020–2023	WR	M
Liaw, S.-S., & Huang, H.-M. (2011). A study of investigating learners' attitudes toward e-learning. <i>ICDLE Proceedings</i> , 12.	GN	A	2010–2019	WR	H
* Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. <i>Cognitive Science</i> , 5.	N/A	A	1981–1999	N/A	H
* Means, B., et al. (2009). Evaluation of evidence-based practices in online learning. U.S. Dept. of Education.	N/A	A	2000–2009	N/A	M
Microsoft. (2021). Microsoft Mesh. [Industry document]. [ST:4. Retained: documents current commercial metaverse platform capabilities directly relevant to the educational deployment feasibility analysis in §5.3.]	N/A	A	2020–2023	N/A	H
* Mitra, A. (1998). Categories of computer use and their relationships with attitudes toward computers. <i>JRCE</i> , 30(3).	GN	A	1981–1999	WR	L
* Mystakidis, S. (2022). Metaverse. <i>Encyclopedia</i> , 2, 486–497.	N/A	A	2020–2023	N/A	H
Nagauleng, A., Waris, A., & Tahir, S. (2018). Psycho-pedagogical aspects of EFL learners' performance: IAIN of Manado.	GS	A	2010–2019	UR	M
Noemí, P.-M., & Máximo, S. H. (2014). Educational games for learning. <i>Universal Journal of Educational Research</i> , 2, 230–238.	N/A	A	2010–2019	N/A	M
Omar, N. D., Hassan, H., & Atan, H. (2012). Student engagement in online learning. <i>Procedia – Social and Behavioral Sciences</i> , 67.	GS	A	2010–2019	NS	M
* Onu, P., Mbohwa, C., & Pradhan, A. (2024). Internet of Production: Industry 4.0 — A comprehensive review. <i>Procedia Computer Science</i> , 232. [ST:4. Retained: platform and connectivity infrastructure analysis in Industry 4.0 contexts, informing §5.2 infrastructure barrier projections.]	N/A	A	2024+	N/A	M
Osman, N. (2020). Digital game-based language learning: A review of research trends. <i>ASM Science Journal</i> , 13.	N/A	A	2020–2023	N/A	M
* Panigrahi, R., Srivastava, P. R., & Sharma, D. (2018). Online learning: Adoption, continuance, and learning outcome — A review. <i>IJIM</i> , 43.	N/A	M	2010–2019	N/A	M
* Paris, P. G. (2004). E-learning: A study on secondary students' attitudes towards online web-assisted learning. <i>International Education Journal</i> , 5.	GN	A	2000–2009	NS	L

Continuation Table:

Source	Geo	Eq	Per	Res	Conf
Peytcheva-Forsyth, R., Yovkova, B., & Aleksieva, L. (2018). Factors affecting students' attitudes towards online learning — Sofia University. AIP Conference Proceedings, 2048.	GN	A	2010–2019	WR	M
* Rhema, A., & Miliszewska, I. (2014). Analysis of student attitudes towards e-learning: Engineering students in Libya. IISIT, 11.	GS	S	2010–2019	UR	H
Sailer, M., Hense, J., Mandl, H., & Klevers, M. (2017). Fostering development of work competencies and motivation via gamification.	GN	A	2010–2019	N/A	L
Sam, H. K., & Wah, T. K. (2008). Acceptance of e-learning among distance learners: A Malaysian perspective. ASCILITE Proceedings.	GS	A	2000–2009	Mx	M
Scherer, R., Siddiq, F., & Tondeur, J. (2019). The TAM: A meta-analytic SEM approach. Computers & Education, 128.	N/A	A	2010–2019	N/A	H
Seemiller, C., & Grace, M. (2017). Generation Z: Educating and engaging the next generation of students. About Campus, 22.	N/A	A	2010–2019	N/A	H
Selim, H. M. (2007). Critical success factors for e-learning acceptance. Computers & Education, 49(2).	GN	A	2000–2009	WR	M
Sharples, M., et al. (2013). Innovating pedagogy 2013. [Open University report]. [ST:4. Retained: Open University report on emerging pedagogies directly informing the educational technology affordance analysis in §5.3; widely cited in the field.]	N/A	M	2010–2019	N/A	M
Singh, S., Kaur, B., & Kaur, K. (2024). Integration of independent and collaborative learning in educational settings. Vol. 5.	N/A	A	2024+	N/A	M
Singh, J., Malhotra, M., & Sharma, N. (2022). Metaverse in education: An overview [Book chapter]. [ST:3. Retained: systematic overview of metaverse applications in education, informing the scope characterisation in §2.1 and §5.4.]	N/A	A	2020–2023	N/A	M
Sivarajah, R. T., et al. (2019). A review of innovative teaching methods. Academic Radiology, 26(1), 101–113.	N/A	A	2010–2019	N/A	H
* Stephenson, N. (1992). Snow crash. Bantam Books. [ST:5. Retained as the foundational source coining the term metaverse; included as background context for §2.1, not as an empirical or analytical unit.]	N/A	A	1981–1999	N/A	H
Stynze Gómez. (2019). Motivational and psycho-pedagogical elements in digital educational materials. Revista Torreón Universitario. [ST:3. Retained: addresses motivational design in digital educational contexts; provides a Global South perspective on gamified learning relevant to §2.3. Conf=M reflects limited indexing of source journal.]	GS	A	2010–2019	UR	M

Continuation Table:

Source	Geo	Eq	Per	Res	Conf
Thorne, M., & MacGregor, C. (2017). Pedagogy and learning for sustainability in a virtual world scaffold [Book chapter]. [ST:3. Retained: addresses pedagogical design in virtual world educational contexts relevant to the transferability analysis in §5.3.]	N/A	A	2010–2019	N/A	L
Warburton, S. (2009). Second Life in higher education. BJET, 40.	N/A	A	2000–2009	N/A	M
* Yusuf, B. N. (2020). A case study of challenges in online learning during COVID-19. ASSRJ, 7(5).	GS	M	2020–2023	Mx	M
Zhang, Z., Cao, T., Shu, J., & Liu, H. (2020). Identifying key factors affecting college students' adoption of e-learning in mandatory blended learning environments. Interactive Learning Environments.	GN	A	2020–2023	WR	M
Zhou, M., & Brown, D. (2015). Educational learning theories (2nd ed.). Galileo Open Textbooks.	N/A	A	2010–2019	N/A	H

Note. An asterisk (*) indicates a source also cited in the prose of the manuscript; full APA 7 references appear in the main References section. Codings reflect the rubric in Table 3 (§4.5). Empirical sources for which population resource context could not be determined are coded N/A on the Res variable; this affects 2 of 28 empirical sources. ST = Source Type: (1) Peer-reviewed empirical study; (2) Systematic review or meta-analysis; (3) Conceptual or theoretical work; (4) Policy, industry, or grey literature document; (5) Background or foundational work.