International Journal of Learning, Teaching and Educational Research
Vol. 24, No. 9, pp. 167-191, September 2025
https://doi.org/10.26803/ijlter.24.9.9
Received Jun 28, 2025; Revised Aug 8, 2025; Accepted Aug 19, 2025

Innovative Pedagogical Models in Mathematics Education: A Systematic Review of Global Challenges, Trends, and Future Research Directions

Usmadi* **and Ergusni**
Muhammadiyah University West Sumatera,
Padang Indonesia

Abstract. This systematic review investigates the evolution of innovative pedagogical models in mathematics education amid mounting global challenges and shifting educational priorities. Synthesizing the findings from 62 peer-reviewed studies, the review highlights how frameworks such as the Universal Design for Learning (UDL), Competency-Based Learning (CBL), blended and HyFlex instruction, ethnomathematics, and culturally responsive pedagogy are reshaping mathematics education toward more inclusive, learner-centered, and technologically adaptive practices. These models have been demonstrated to have significant benefits when it comes to enhancing student engagement, agency, and differentiated achievement, especially in culturally and linguistically diverse contexts. However, their implementation remains geographically and structurally uneven, with high-income countries (HICs) enjoying greater institutional support and infrastructure, while low- and middle-income countries (LMICs) face systemic constraints. The review identifies three strategic imperatives for advancing future practice and research: context-sensitive co-design, methodological diversification, and systemic integration across policy and practice. Overall, this study affirms the transformative potential of innovative pedagogies to address global disparities and position mathematics education as a catalyst for educational equity, lifelong learning, and sustainable development.

Keywords: Mathematics education; innovative pedagogy; global educational challenges; systematic literature review; future research directions

*Corresponding author: Usmadi; *usmadi3012@gmail.com*

1. Introduction

Global education stands at a critical juncture, marked by deepening disparities in access, instructional quality, and learning outcomes. Structural inequities—driven by poverty, conflict, and systemic exclusion—continue to obstruct efforts toward inclusive and equitable education. A stark indicator of this crisis is the rise in "learning poverty," defined as the inability to read and understand a simple text by age ten. In low-income countries, over 70% of children fall into this category, reflecting foundational gaps in early education (World Bank, 2022; UNESCO, 2023). These deficiencies not only hinder individual potential but also undermine national development and global equity goals (UNICEF, 2023).

In mathematics education, these inequities are especially evident. Traditional teacher-centered models focused on rote learning often neglect conceptual understanding and critical thinking (Schleicher, 2022). Furthermore, curricula frequently lack cultural and contextual relevance, overlooking the linguistic, cognitive, and social diversity of learners, particularly in under-resourced environments (Tikly, 2019). This disconnect contributes to disengagement, widens achievement gaps, and curtails learner agency. Addressing these challenges requires a shift toward inclusive, responsive, and empowering pedagogies.

The global digital divide further exacerbates educational inequality. While digital tools have the potential to broaden access and improve learning, disparities in infrastructure, connectivity, device access, and digital literacy continue to limit meaningful use, especially in low- and middle-income countries (Van Dijk, 2020; Trucano & Iglesias, 2021). As blended and hybrid models gain traction, there is an urgent need for equity-driven digital pedagogies adapted to diverse contexts. In response, research increasingly points to transformative instructional models that emphasize flexibility, learner agency, and inclusion. Four key frameworks—Problem-Based Learning (PBL), Universal Design for Learning (UDL), Competency-Based Learning (CBL), and Technology-Enhanced Learning (TEL)—have emerged as promising strategies to confront the inequities in mathematics education.

PBL fosters inquiry-based engagement with real-world problems, promoting critical thinking, collaboration, and deeper cognitive processing (Barrows, 2012; Hmelo-Silver, 2004; Capraro et al., 2013; Kokotsaki et al., 2016). UDL, informed by cognitive neuroscience, supports inclusive design by addressing learner variability and ensuring access for all, particularly in multilingual and neurodiverse settings (Meyer et al., 2014; Rao et al., 2021; Basham et al., 2020). CBL shifts focus from time-based progression to mastery, supporting personalized pathways and metacognitive development, which is at the core of mathematical competence (Le et al., 2014; Pane et al., 2015; Patrick et al., 2016). TEL offers differentiated instruction, scalable resources, and real-time feedback but its impact remains highly contingent on infrastructure, digital skills, and cultural alignment (Bond et al., 2021; Tondeur et al., 2017; Van Dijk, 2020).

Despite their promise, these approaches face implementation challenges. Success depends on system-level alignment, specifically coherent policy, teacher preparation, and community engagement (Darling-Hammond et al., 2020; Fullan, 2021). Insufficient attention to cultural relevance and indigenous knowledge systems limits their effectiveness in marginalized and conflict-affected settings (Tikly, 2019; Bozkurt et al., 2020). This systematic literature review investigates how learner-centered pedagogies address global challenges in mathematics education. It is guided by three questions: (1) What models are being used to reduce inequities in mathematics learning? (2) What implementation patterns and impacts are evident across contexts? (3) What strategies are needed to ensure scale, equity, and contextual relevance?

Drawing on 62 peer-reviewed studies published between 2013 and 2024, the review synthesizes the current evidence on transformative pedagogies and their role in building inclusive, high-quality mathematics education systems. It also identifies persistent gaps, including limited longitudinal research, underrepresentation in low-resource contexts, and weak policy integration. The review concludes with recommendations for future research and systemic reform to support equitable, context-responsive learning environments worldwide.

2. Literature Review

2.1. Global Education Challenges and the Pursuit of Equity in Mathematics Education

Despite decades of reform, education systems worldwide continue to face entrenched inequities, particularly in mathematics. These challenges—rooted in generational poverty, systemic marginalization, and conflict—limit access to quality instruction and hinder the development of foundational numeracy (UNESCO, 2023). The World Bank's (2022) notion of "learning poverty," originally focused on reading, extends to mathematics where over 70% of children in low-income contexts lack basic competencies such as number sense and logical reasoning.

Traditional, teacher-centered instruction often emphasizes procedural repetition over conceptual understanding, neglecting the linguistic, cognitive, and socio-cultural diversity of learners (Schleicher, 2022). In multilingual classrooms across the Global South, these approaches fail to support meaningful engagement. The digital divide—exacerbated by COVID-19—has further widened learning gaps, especially in mathematics (Van Dijk, 2020; Kaffenberger & Pritchett, 2021).
Addressing these intersecting barriers demands inclusive, equity-driven pedagogies aligned with 21st-century skills.

2.2. The Rise of Innovative Pedagogical Models in Mathematics Education

Emerging pedagogies offer promising alternatives to rigid, test-driven instruction. These learner-centered models foster deeper engagement, critical thinking, and inclusivity. Problem-Based Learning (PBL) builds conceptual understanding through real-world inquiry, enhancing reasoning, collaboration, and persistence (Hmelo-Silver, 2004; Yew & Goh, 2016). Universal Design for Learning (UDL) promotes access through varied representations and pathways for engagement, meeting diverse learner needs (Katz & Sokal, 2016). Competency-Based Learning (CBL) emphasizes mastery over seat time, enabling personalized progress (Le et al., 2014; Pane et al., 2017). Technology-Enhanced Learning (TEL) bridges instructional gaps using adaptive tools and blended platforms, which is particularly beneficial in under-resourced settings (Bond et al., 2021; Ifenthaler & Yau, 2020). Together, these models signal a shift toward responsive, student-driven mathematics education, which is essential for a complex, globalized world (Sahin & Top, 2015).

2.3. Systematic Reviews and Emerging Themes in Pedagogical Innovation

Systematic reviews consolidate the global evidence on the impact and scalability of innovative pedagogies. Studies consistently report gains in student motivation, critical thinking, and equity, especially when models are implemented with fidelity (Boelens et al., 2018; Salinas et al., 2022). These outcomes reflect the growing support for student-centered learning environments.

However, widespread adoption remains limited. Many innovations lack policy integration, sustained teacher support, and cultural relevance (Cojocariu & Boghian, 2020). Moreover, research disproportionately focuses on high-income contexts, raising concerns about global equity. Future studies should emphasize culturally responsive design, long-term impact evaluation, and scalable implementation strategies. Advancing these areas is crucial for embedding innovation within resilient and equitable education systems.

2.4. Pedagogical Innovation and the Imperative for Contextual Responsiveness

While pedagogical innovations offer tools for addressing educational inequities, their success depends on context-sensitive implementation. Universal models often fall short in linguistically diverse, socioeconomically marginalized, or post-conflict settings (Tikly, 2019). Approaches like PBL, UDL, and CBL must be adapted to local cultures, institutional realities, and the learners' lived experiences.

Implementation fidelity hinges on the teachers' professional capacity. Without adequate training, mentorship, and institutional backing, even proven methods yield limited results, especially in under-resourced environments lacking materials, infrastructure, and supportive policies (Darling-Hammond et al., 2020; Bozkurt et al., 2020).

Effective reform requires a systemic approach, inclusive of integrating curriculum redesign, inclusive assessment, and ongoing professional learning. Only through such comprehensive efforts can pedagogical innovation support equity-driven transformation in mathematics and beyond.

2.5. Learning Equity in Contemporary Education

Learning equity is a pressing global concern, shaped by disparities in access, participation, and achievement. True equity goes beyond equal access; it demands differentiated support, inclusive curricula, and culturally responsive environments that foster success for all learners (OECD, 2020; Banks & Obiakor, 2015).

Persistent barriers—including underfunded schools, misaligned curricula, and high dropout rates—are often rooted in postcolonial structures and global policy frameworks that neglect local realities (Tikly, 2011; Reimers & Schleicher, 2020). In rural and low-income areas, inequities are worsened by teacher shortages and infrastructure deficits, particularly in STEM.

The COVID-19 pandemic intensified these divides. Sudden transitions to digital learning exposed widespread gaps in device access, internet stability, and digital literacy (Trucano & Iglesias, 2021; Tadesse & Muluye, 2020). As Bozkurt et al. (2020) note, learners in fragile systems face disproportionate challenges. Addressing these inequities requires systemic reform: inclusive curricula, differentiated instruction, community partnerships, and equitable digital access (Darling-Hammond et al., 2020; Zhao, 2020). Embedding these principles into policy and practice is vital for building resilient, inclusive, and future-ready education systems.

2.6. Educational Models for Inclusive and Adaptive Learning

Educational models serve as both structural and philosophical anchors for designing responsive learning environments. Recent developments emphasize flexibility, inclusivity, and learner-centeredness. The Universal Design for Learning (UDL) offers a proactive framework that addresses learner diversity by incorporating multiple means of representation, engagement, and expression—embedding accessibility into instruction from the outset (Meyer et al., 2014).

Competency-Based Learning (CBL) redefines progress by emphasizing mastery over time spent, allowing learners to advance based on demonstrated understanding (Le et al., 2014). Similarly, Project- and Problem-Based Learning (PBL) connect learning to real-world contexts, fostering critical inquiry, student agency, and interdisciplinary thinking (Hmelo-Silver, 2004). These models support equity by allowing differentiation and contextual adaptation.

Technology-Enhanced Learning (TEL) further expands inclusivity by offering personalized, scalable instruction through digital platforms and data-informed feedback, all of which are crucial for underserved or remote settings (Bond et al., 2021). Collectively, these approaches signal a paradigm shift toward inclusive, adaptive learning ecosystems designed to meet the evolving demands of contemporary education.

2.7. Embedding 21st-Century Skills in Pedagogical Practice

As societies transition into knowledge-based economies, cultivating 21st-century skills—including critical thinking, creativity, collaboration, communication, and digital literacy—has become a pedagogical imperative (Binkley et al., 2012). However, meaningful integration requires more than curricular additions; it demands transformative pedagogies, adaptive assessments, and supportive ecosystems.

Approaches like inquiry-based learning and flipped classrooms exemplify this shift by promoting active participation, autonomy, and real-world application (Boelens et al., 2018). Technology enhances these practices by enabling interactive collaboration, feedback, and self-regulated learning. Still, equitable integration remains contingent on system-level capacity. Without comprehensive teacher training, strong leadership, and reliable infrastructure, efforts to embed these skills risk deepening the existing inequalities. Thus, building future-ready learners requires holistic reform, aligning innovation with structural equity and sustainability.

3. Methodology

3.1. Methodological Framework

This study employed a Systematic Literature Review (SLR) guided by PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), ensuring methodological rigor, transparency, and replicability (Page et al., 2021). The review aimed to identify, assess, and synthesize peer-reviewed research on innovative pedagogical models addressing global educational challenges. The process followed four structured phases—identification, screening, eligibility, and inclusion—while adhering to international standards for evidence-based synthesis.

3.2. Databases and Search Strategy

Three leading academic databases—Scopus, Web of Science, and ERIC—were selected for their comprehensive coverage of interdisciplinary educational research. A Boolean-enhanced search strategy was used to balance precision and inclusivity. The final search string was:
("innovative pedagogy" OR "learning model" OR "instructional design") AND ("global education challenge" OR "learning crisis" OR "education inequality") AND ("systematic review").

Searches were conducted in April 2024, limited to peer-reviewed articles in English published between 2013 and 2024. This timeframe captures a decade of scholarship following the post-2012 global education reforms, particularly the implementation of Sustainable Development Goal 4 (SDG 4), which prioritizes inclusive and equitable quality education (UNESCO, 2023). The selected period reflects contemporary, policy-relevant innovation and structural responses to persistent disparities in access, quality, and equity in education.

3.3. Inclusion Criteria

To ensure transparency and methodological rigor, the following inclusion criteria were established prior to the literature selection process. These criteria guided the identification and selection of studies that were both thematically relevant and academically robust. A summary of the applied inclusion parameters is presented in Table 1 below.

Table 1: Inclusion criteria of the systematic review

Criterion Category	Inclusion Criteria	Rationale
Publication Type	Peer-reviewed journal articles only	Ensures academic rigor and credibility
Publication Period	January 2013 - 2024	Captures a decade of pedagogical reform aligned with SDG 4 and post-2012 global education discourse
Language	English	Allows consistent analysis and interpretation
Full-text Availability	Full text must be accessible	Ensures comprehensive evaluation of the study content
Thematic Focus	Must focus on innovative pedagogical models or instructional frameworks addressing global/systemic educational challenges (e.g., equity, inclusion, access)	Aligns with review objectives targeting transformative and inclusive education
Research Type	Empirical studies (qualitative, quantitative, mixed methods), systematic reviews, meta-analyses, or conceptual/theoretical models with pedagogical implications	Ensures diversity of methods examined and inclusion of substantial scholarly contributions
Scholarly Contribution	Must offer conceptual innovation, critical synthesis, or practical insights for education policy or classroom pedagogy	Promotes relevance, depth, and applicability of findings

3.4. Exclusion Criteria

To complement the inclusion criteria and uphold the integrity of the systematic review, a set of exclusion parameters was also defined. These criteria were applied to eliminate studies that lacked methodological rigor, thematic relevance, or conceptual generalizability. The specific exclusion criteria used to filter out ineligible literature have been summarized in Table 2 below.

Table 2: Exclusion criteria of the systematic review

Criterion Category	Exclusion Criteria	Rationale
Publication Type	Editorials, opinion pieces, commentary essays, book reviews, and conference abstracts	Lack empirical or theoretical rigor; absence of methodological transparency (Gough, Oliver, & Thomas, 2017)
Scope and Generalizability	Studies with overly narrow/localized focus or isolated case studies without transferability or conceptual scalability	Do not contribute to broader, generalizable pedagogical discourse (Peters et al., 2020)
Thematic Misalignment	Research not directly addressing innovative pedagogy, learning equity, or systemic educational challenges	Lacks relevance to the core objectives and analytical framework of the review
Language	Non-English publications	Ensures consistency in language for in-depth analysis and cross-comparison
Accessibility	Articles not available in full-text format	Prevents thorough appraisal of methodological and conceptual contributions

3.5. Screening and Selection Process

The selection process followed the PRISMA 2020 guidelines to ensure transparency and rigor in identifying relevant studies. A total of 321 records were initially retrieved from four major databases. After removing duplicates and conducting a structured screening based on the titles, abstracts, and full texts, 62 studies met the inclusion criteria. The details of the flow of the selection process are presented in Table 3.

Table 3: PRISMA Flow Summary – Study Selection Process

PRISMA Stage	Description
Identification	Records identified from databases: Scopus (n = 134), Web of Science (n = 79), ERIC (n = 52), Google Scholar (n = 56); Total = 321
After Duplicates Removed	Records remaining after duplicate removal: 295
Screening	Titles and abstracts screened: 295 records excluded: 181
Eligibility	Full-text articles assessed for eligibility: 114 Full-text articles excluded: 53– Not related to mathematics education (n = 23)– No pedagogical content (n = 17)– Low methodological quality (n = 13)
Included	Studies included in the final review: 62– Empirical studies: 46– Review studies: 16

The study selection process adhered strictly to the PRISMA 2020 guidelines, ensuring methodological transparency at each stage of the systematic review. The identification phase yielded a total of 321 records retrieved from four academic databases: Scopus (n = 134), Web of Science (n = 79), ERIC (n = 52), and Google Scholar (n = 56). After the removal of duplicate entries, 295 unique records remained and were subsequently screened based on the titles and abstracts.

During the screening phase, 181 articles were excluded due to misalignment with the study's scope. The remaining 114 articles underwent full-text assessment for eligibility. Here, 53 records were excluded for the following reasons: not focused on mathematics education (n = 23), absence of pedagogical content (n = 17), and insufficient methodological quality (n = 13). Ultimately, 62 studies met all inclusion criteria and were incorporated into the final synthesis. These were comprised of 46 empirical studies and 16 systematic or theoretical reviews.

3.6. Data Analysis

The final pool of 62 studies was analyzed using **thematic synthesis**, a qualitative meta-synthesis method suited to interpreting findings across diverse study designs. Following the framework proposed by Thomas and Harden (2008), the process was comprised of three stages: (1) line-by-line coding of the finding's sections, (2) the development of descriptive themes that reflect surface-level meanings, and (3) the generation of analytical themes offering higher-order, cross-contextual insights.

This method was well-suited to the corpus, which included qualitative, quantitative, and mixed-methods studies. It enabled the identification of recurring pedagogical patterns, emerging theoretical constructions, and nuanced interpretations of equity and innovation in global education.

To ensure rigor and transparency, NVivo 14 was used for coding, thematic mapping, and traceability. The resulting synthesis was structured into three overarching themes: (1) pedagogical innovation, (2) equity-centered outcomes, and (3) alignment with 21st-century competencies. These themes form the analytical framework for the findings presented in the next section.

4. Results

4.1. Transformative Shifts in Mathematics Pedagogy: Toward Equity, Adaptability, and Innovation

Contemporary mathematics education is undergoing a significant shift toward learner-centered, adaptive, and technology-integrated approaches. This transformation responds to persistent global inequities and the growing demand for 21st-century competencies. Traditional, teacher-led instruction—often reliant on procedural repetition—is increasingly being replaced by constructivist pedagogies that promote critical thinking, collaboration, and real-world problem-solving (Hmelo-Silver, Duncan, & Chinn, 2015; Savery, 2015).

Problem-Based Learning (PBL) exemplifies this shift by engaging students in interdisciplinary problems requiring collaborative inquiry and mathematical reasoning. Evidence shows that PBL enhances conceptual understanding, metacognitive growth, and learner autonomy, especially in under-resourced settings (Dolmans et al., 2016; Yew & Goh, 2016). When culturally adapted, it also fosters inclusivity and engagement among marginalized learners (Hung, 2013; Spector, 2022).

Universal Design for Learning (UDL) has gained prominence for enabling inclusive and differentiated mathematics instruction. By offering multiple modes of representation, expression, and engagement, UDL addresses the cognitive, linguistic, and socio-emotional diversity present in modern classrooms (Meyer, Rose, & Gordon, 2014). Practices such as visual aids, manipulatives, narrative scaffolding, and interactive tools have proven especially effective for multilingual and neurodiverse learners (Katz & Sokal, 2016; Rao et al., 2021), contributing to greater persistence, equity, and positive mathematical identity (Al-Azawei et al., 2016).

Competency-Based Learning (CBL) shifts focus on the change from time-bound progression to demonstrated mastery. This model supports individualized pacing and targeted remediation, which are critical in a discipline where understanding builds cumulatively (Le et al., 2014; Pane et al., 2017). CBL not only fosters self-directed learning but also addresses opportunity gaps by accommodating diverse learning trajectories (Jääskelä et al., 2023; UNESCO, 2023).

The COVID-19 pandemic further accelerated the integration of Technology-Enhanced Learning (TEL). Tools such as adaptive platforms, gamified apps, AI analytics, and hybrid models support personalized instruction, real-time assessment, and flexible delivery (Bond et al., 2021; Ifenthaler & Yau, 2020). In mathematics specifically, platforms like GeoGebra, Desmos, and intelligent tutoring systems have enhanced engagement and problem-solving skills (Holmes et al., 2022; Kapur et al., 2018). However, the impact of TEL depends on pedagogical coherence, contextual fit, and sustained teacher development (Mäkitalo et al., 2021; Selwyn, 2016).

Collectively, these innovations reflect a move from rigid, standardized instruction to responsive, inclusive, and context-aware pedagogical frameworks. When grounded in equity and adapted to local socio-economic realities, such approaches yield significant gains in mathematical understanding, learner engagement, and socio-emotional development, even in fragile or underfunded settings (Outhwaite et al., 2020; Winthrop & Ziegler, 2021). Pedagogical innovation, therefore, stands as a powerful lever for advancing educational quality and inclusion on a global scale.

To consolidate insights from the evolving landscape of instructional practice, Table 4 presents a synthesized comparison of the key pedagogical models in mathematics education, detailing their core characteristics, targeted learning outcomes, and contextual applications based on the scholarly literature published between 2013 and 2024.

Table 4: Summary of innovative pedagogical models in mathematics education

Model	Key Features	Mathematical Goals	Contextual Applications	Representative Studies
Problem-Based Learning (PBL)	Real-world problems, collaborative inquiry, student-driven exploration	Critical thinking, application, reasoning, collaboration	Secondary and higher education, inclusive and multicultural settings	Hmelo-Silver et al. (2015); Yew & Goh (2016); Hung (2013)
Universal Design for Learning (UDL)	Multiple means of representation, engagement, and expression	Accessibility, equity, engagement, differentiation	K–12 diverse learners, special education integration	Meyer et al. (2014); Katz & Sokal (2016); Rao et al. (2021)
Competency-Based Learning (CBL)	Mastery progression, flexible pacing, outcomes-driven	Deep understanding, personalized progression, feedback-informed learning	Blended learning environments, both low- and high-resource systems	Le et al. (2014); Pane et al. (2017); Jääskelä et al. (2023)
Technology-Enhanced Learning (TEL)	Digital platforms, AI tools, simulations, gamification	Autonomy, formative feedback, scalable instruction	COVID/post-COVID recovery, rural and urban integration	Bond et al. (2021); Holmes et al. (2022); Kapur et al. (2018); Ifenthaler & Yau (2020)

Source: PRISMA Process Screening Results

4.2. Gaps and Limitations in the Current Research

Despite the growing consensus on the potential of learner-centered and technology-enhanced pedagogies, several persistent challenges limit their transformative capacity, particularly in advancing equity in mathematics education.

First, the global research base is disproportionately concentrated in high-income countries (HICs), especially in North America, Western Europe, and East Asia (Bond et al., 2021; Dobozy & Pospisil, 2014). This imbalance raises concerns about the contextual relevance and scalability of widely promoted models such as PBL, CBL, and UDL in low- and middle-income countries (LMICs). In regions like Sub-Saharan Africa and Southeast Asia—including Indonesia—educational reform is often constrained by weak digital infrastructure, limited teacher training, and complex sociocultural dynamics (Tikly, 2020; Winthrop & Ziegler, 2021). Additional barriers, such as multilingual classrooms, rigid national curricula, and structural inequities, further hinder effective implementation.

Second, many studies rely on short-term, small-scale interventions that fail to capture the systemic or sustained impact of reform (Holmes et al., 2022; Means et al., 2014). While such studies offer useful insights, they often overlook long-term gains in foundational competencies like abstraction, reasoning, and communication (Sfard, 2015). Given the cumulative nature of mathematics learning, longitudinal and system-wide research is essential.

Third, reform initiatives are frequently disconnected from broader educational ecosystems, resulting in misalignment with national standards, assessments, and teacher development systems (Fullan, 2021; Reimers, 2022). In mathematics education, this fragmentation weakens institutional ownership, reduces implementation fidelity, and undermines sustainability.

Fourth, equity concerns related to digital learning remain under-theorized and under-researched. Although the COVID-19 pandemic accelerated technology adoption, issues such as algorithmic bias, unequal access, and limited teacher digital capacity remain unresolved (Selwyn, 2016; UNESCO, 2023). Without inclusive frameworks, technology risks exacerbating—rather than mitigating—existing disparities.

Collectively, these challenges underscore the need for inclusive, policy-aligned, and context-grounded research agendas. Future work must prioritize equity-centered cross-cultural studies that integrate culturally responsive pedagogies, robust teacher training, and systemic alignment across policy, infrastructure, and professional development.

To inform this direction, Table 5 provides a thematic synthesis of the reviewed literature, outlining the key pedagogical innovations, targeted 21st-century competencies, regional focuses, and any enabling or limiting conditions. This framework offers a strategic lens for designing scalable and inclusive mathematics education reforms.

Table 5. Thematic synthesis of the reviewed literature on mathematics education

Pedagogical Innovation	Targeted 21st-Century Competencies	Geographic Focus	Enabling / Limiting Factors	Key References
Problem-Based Learning (PBL)	Critical thinking, collaboration, problem-solving	North America, East Asia, Sub-Saharan Africa	✅ Promotes real-world engagement and active learning . Often constrained by curriculum rigidity and teacher-centered traditions	Hmelo-Silver et al. (2015); Yew & Goh (2016); Hung (2013); Spector (2022)
Competency-Based Learning (CBL)	Self-regulation, mastery orientation, personalized pacing	Finland, US, Southeast Asia	✅ Supports individualized progression and remediation. Misalignment with traditional time-based standards and assessments	Le et al. (2014); Pane et al. (2017); Jääskelä et al. (2023)

Universal Design for Learning (UDL)	Cognitive flexibility, inclusivity, expressive engagement	Canada, Australia, Indonesia	✅ Enables multimodal access and responsive instruction. Requires intensive teacher preparation and system's level buy-in	Meyer et al. (2014); Katz & Sokal (2016); Rao et al. (2021); Al-Azawei et al. (2016)
Technology-Enhanced Learning (TEL)	Digital fluency, learner autonomy, adaptability	Global (especially post-pandemic)	✅ Facilitates scalable, data-driven, and differentiated learning. Impact limited by the digital divide, algorithmic bias, and teacher digital readiness	Bond et al. (2021); Holmes et al. (2022); Ifenthaler & Yau (2020); Selwyn (2016)
Inquiry-Based Learning / Flipped Classroom	Communication, inquiry skills, learner agency	Western Europe, Latin America	✅ Encourages student-led learning and deeper understanding. Challenging to implement without cultural/pedagogical paradigm shifts	Boelens et al. (2018); Savery (2015); Sfard (2015)
Culturally Responsive Pedagogy (CRP)	Socio-emotional learning, identity formation, inclusivity	Indigenous and multilingual contexts (e.g., NZ, Indonesia)	✅ Enhances relevance, equity, and learner voice. Often marginalized in standardized curricula and assessment frameworks	Tikly (2020); Winthrop & Ziegler (2021); UNESCO (2023)

Source: Prisma process screening results

Despite the increasing global endorsement of instructional models such as Problem-Based Learning (PBL), the Universal Design for Learning (UDL), Competency-Based Learning (CBL), and Technology-Enhanced Learning (TEL), significant gaps remain in their equitable and context-responsive implementation, particularly across mathematics education systems in the Global South. Although PBL and UDL present robust frameworks for fostering inclusive, differentiated learning, their practical adoption is often hindered by structural inertia, limited policy traction, and weak institutional commitment. Similarly, while CBL and TEL offer high potential for personalization and scalability, their systemic integration is frequently obstructed by rigid assessment regimes, inadequate digital infrastructure, and fragmented reform efforts.

These limitations constrain the transformative impact of such pedagogies and risk reinforcing the existing inequities in the access to quality mathematics instruction. Moreover, culturally responsive pedagogies—which are essential for contextual relevance, learner engagement, and identity development—remain under-researched, under-utilized, and insufficiently embedded within national education systems. Empirical evidence of their effectiveness is sparse, and their integration into curricular policy and teacher training frameworks is often superficial or absent.

To synthesize these challenges and opportunities, Table 6 presents a thematic matrix that maps the key intersections between pedagogical innovations and critical dimensions of equity, inclusion, and systemic transformation. This framework is designed to inform educators, researchers, and policymakers in mobilizing evidence-based instructional strategies to redress structural disparities and advance mathematics education systems that are inclusive, locally relevant, and future-ready.

Table 6: Thematic synthesis of pedagogical innovations in response to global educational challenges

Core Theme	Description of Findings	Representative Models	Contributions to Global Educational Challenges	Systemic Constraints	Supporting References
1. Digital and Technology-Enhanced Learning	Technology-driven models expand access, enable personalized learning, and support flexible pathways across contexts	MOOCs, Flipped Classrooms, AI-Personalized Platforms, Digital Assessment Tools	Expands reach to underserved learners; supports differentiated instruction; enables remote and hybrid learning	Digital divide; algorithmic bias; limited digital pedagogy training for educators	Holmes et al. (2022); Sun et al. (2022); Zawacki-Richter et al. (2019); Almahasees et al. (2021); Veletsianos & Houlden (2020); Trust et al. (2021); Bozkurt & Sharma (2020); Mishra et al. (2020); Ahn et al. (2023); Selwyn (2023)
2. Project-Based and Collaborative Learning	Promotes deep learning through real-world inquiry, problem solving, and teamwork across disciplines	Project-Based Learning (PBL), STEM-Integrated Design, Collaborative Inquiry Learning	Develops transversal skills: creativity, critical thinking, collaboration, problem-solving	Lack of teacher preparedness; weak alignment with national curriculum standards and assessments	Bell (2010); Wrigley (2016); Larmer et al. (2015); Blumenfeld et al. (2022); Hung (2021); Hmelo-Silver et al. (2022); Krajcik & Shin (2021)
3. Equity, Inclusion, and Culturally Responsive Pedagogy	Centers learners' identities, languages, and cultural heritage to	Culturally Responsive Pedagogy, Ethnomathematics, Multilingual	Narrows achievement gaps; affirms learners' identities; supports localized	Scarce empirical validation; weak integration in national	Paris & Alim (2017); Gay (2018); Powell & Frankenstein (2020); McKinley & Tuhiwai Smith (2019);

	foster belonging and equity	Instruction, Indigenous Knowledge Integration	curriculum development	education systems	Tikly (2020); Winthrop & Ziegler (2021); Ladson-Billings (2021); de Oliveira et al. (2023)
4. Critical and Transformative Pedagogies	Engages learners in confronting structural injustice, fostering ethical agency and global citizenship	Freirean Pedagogy, Critical Digital Pedagogy, Transformative Learning, Decolonial Education	Cultivates critical awareness and agency; promotes democratic participation and social justice	Marginalized in formal curricula; politically sensitive in some systems	Darder (2017); McLaren (2015); Stommel (2014); Andreotti (2021); Reimers (2022); Carr & Thésée (2023); Giroux (2020)
5. Crisis-Responsive and Adaptive Learning Models	Emerged in response to COVID-19, climate crises, and conflict, emphasizing resilience and continuity	HyFlex Models, Emergency Remote Teaching (ERT), Resilient Learning Frameworks, Adaptive Instruction	Sustains education during emergencies; supports flexible modalities and psychological safety	Lacks integration into long-term policy; highly reactive; under-researched in LMICs	Bozkurt et al. (2020); Hodges et al. (2020); König et al. (2020); Reimers et al. (2021); Schleicher (2020); Salmi (2021); Trust & Whalen (2020); UNESCO (2023); Zhao (2020); Kim et al. (2023); Houlden & Veletsianos (2024)

Source: Prisma process screening results

4.3. Thematic Synthesis and Critical Insights

Table 6 underscores the fragmented and uneven implementation of pedagogical innovations in mathematics education, particularly concerning equity, inclusion, and systemic reform. Technology-enhanced models—such as MOOCs, flipped classrooms, and AI-driven platforms—have broadened access and enabled personalization. Yet persistent digital divides, limited teacher digital fluency, and algorithmic bias remain significant barriers in low- and middle-income contexts (Outhwaite et al., 2020; Winthrop & Ziegler, 2021).

Project-based and collaborative learning foster critical thinking, creativity, and teamwork but often face obstacles due to curriculum misalignment, weak policy integration, and limited teacher preparation (Hmelo-Silver et al., 2015; Dolmans et al., 2016). Culturally responsive approaches, including ethnomathematics, support identity development and contextual learning, although empirical validation across diverse contexts remains limited (D'Ambrosio, 2016; Barton, 2021).

Critical pedagogies rooted in Freirean and decolonial thought promote agency, dialogue, and justice. Despite their promise, they remain peripheral due to political resistance and institutional inertia (Freire, 1970; Giroux, 2020). Similarly, crisis-driven models like HyFlex and emergency remote teaching provide short-term solutions but lack integration into long-term strategies (Bozkurt et al., 2020; Trust & Whalen, 2021).

While many innovations reflect global reform priorities, their impact is undermined by policy fragmentation, inconsistent implementation, and weak evidence of sustained outcomes. Advancing inclusive and scalable models demands greater policy coherence, cross-sector collaboration, and long-term research, particularly in under-resourced settings.

4.4 Review Methodology Summary

This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. An initial pool of 321 records was retrieved from Scopus, Web of Science, ERIC, and Google Scholar. After removing duplicates and conducting a multi-stage screening process (title, abstract, and full-text review), 62 peer-reviewed articles published between 2013 and 2024 were included in the final synthesis. The inclusion criteria required studies to: (1) explicitly examine pedagogical innovation in mathematics education; (2) address global educational challenges; (3) employ empirical, systematic, or mixed-methods approaches; and (4) appear in Scopus-indexed journals (Q1–Q3). Editorials, non-English publications, and conceptual essays lacking methodological transparency were excluded.

The final corpus offers a robust and diverse evidence base, covering a wide range of instructional models from technology-enhanced and project-based learning to culturally responsive and equity-oriented pedagogies. While notable advancements are evident, the field remains fragmented. Strengthening the impact of pedagogical innovation requires greater methodological rigor, deeper contextual grounding, and stronger alignment with national education systems, especially in under-resourced contexts. Such alignment is critical to ensure that innovation not only enhances instructional quality but also drives structural equity and long-term transformation in mathematics education globally.

5. Discussion

This review underscores a global shift in mathematics education from traditional, didactic instruction to learner-centered, digitally supported, and culturally responsive approaches. Central to this transformation is the growing emphasis on personalization, flexibility, and 21st-century competencies such as critical thinking, creativity, collaboration, and communication (Saavedra & Opfer, 2012; OECD, 2023). Frameworks like Universal Design for Learning (UDL), Competency-Based Learning (CBL), and hybrid models (e.g., blended, HyFlex) offer adaptable and inclusive learning pathways (Rose et al., 2018; Beatty, 2019; DeLorenzo & Battino, 2021; Chikwendu & Owusu, 2024).

However, research and implementation remain uneven. Over 70% of the 62 reviewed studies originate from high-income countries, with limited representation from low- and middle-income contexts such as Sub-Saharan Africa, Southeast Asia, and Latin America (Tikly, 2019; Trucano & Iglesias, 2021; Adebayo et al., 2025). This imbalance raises questions about contextual relevance and global equity. The promise of UDL depends on access to assistive technologies, professional development, and institutional support—resources that are often lacking in LMICs (Al-Azawei et al., 2017; Hassan et al., 2024). Likewise, CBL faces challenges including rigid assessments, policy fragmentation, and infrastructure deficits (Winthrop & McGivney, 2016; Le et al., 2014; UNESCO, 2021; Yusof & Lee, 2025). Technology-enhanced learning (TEL) shows potential but yields mixed outcomes.

Adaptive platforms, flipped classrooms, and AI tools succeed in digitally advanced settings but often falter in low-resource environments due to limited access, low digital literacy, and culturally mismatched content (Bozkurt et al., 2020; Trust & Whalen, 2020; Singh & Widodo, 2025). These challenges highlight the need for locally adapted linguistically relevant solutions (UNESCO, 2024). Culturally sustaining pedagogies, including ethnomathematics and localized STEM, are gaining traction by affirming learner identity and challenging Eurocentric norms (Zulu & Mkhize, 2024; Tomašič & Chabwera, 2025). Yet the empirical evidence remains limited, with few large-scale or longitudinal studies (Reimers, 2022; Narayan & Kumari, 2025).

Sustainable innovation requires systemic coherence— an alignment across the curriculum, assessment, teacher preparation, and policy (Darling-Hammond et al., 2020; Fullan, 2021; Ngugi & Patel, 2025). The COVID-19 pandemic exposed deep inequities but also accelerated experimentation. While emergency remote teaching ensured continuity, it lacked pedagogical rigor and often excluded vulnerable learners (Hodges et al., 2020). HyFlex and blended learning models offer flexibility but demand long-term investment in infrastructure, localized content, and educator capacity—areas where LMICs continue to lag (Beatty, 2019; Banerjee et al., 2024).

Moving forward, equity, cultural relevance, learner agency, and systemic integration must guide pedagogical innovation. No single model fits all. Sustainable solutions must be co-designed with local communities and embedded in diverse educational ecologies. Bridging innovation with equity is the key to building inclusive and future-ready mathematics education systems (UNESCO, 2021; OECD, 2023; Education Futures Alliance, 2025).

6. Conclusion and Implications

This systematic review reveals a global shift in mathematics education toward pedagogical models that prioritize equity, inclusivity, and contextual relevance. Across 62 studies, the evidence consistently affirms the impact of Universal Design for Learning (UDL), Competency-Based Learning (CBL), Project- and Problem-Based Learning (PBL), and Technology-Enhanced Learning (TEL) in fostering engagement, differentiated achievement, and participation, particularly in culturally and linguistically diverse contexts. When embedded within coherent, system-wide strategies, these models contribute meaningfully to educational transformation. However, widespread implementation remains uneven. In low- and middle-income countries (LMICs), adoption is frequently constrained by rigid curricula, inequitable resource allocation, weak digital infrastructure, and limited professional development. These systemic barriers hinder both scalability and the localization of equity-centered innovations.

Three key imperatives emerged for advancing inclusive and sustainable reform. First, pedagogical approaches must be co-designed with educators, learners, and communities to ensure cultural relevance and contextual fit. Second, there is a pressing need to expand the empirical base, particularly through rigorous, longitudinal, and mixed-method studies in underrepresented regions of the Global South. Third, innovation must be systemically aligned and supported by coherent policies spanning curriculum design, assessment reform, teacher training, and equitable digital access.

The COVID-19 pandemic amplified existing inequities, with emergency remote instruction often excluding marginalized learners. Yet, in well-resourced contexts, hybrid and HyFlex models demonstrated resilience and adaptability, underscoring the importance of sustained investment and strategic planning. Looking ahead, the future of mathematics education lies in cross-sector collaboration and a fundamental reimagining of mathematics as a tool for critical inquiry, social justice, and global citizenship. Equity must not be treated as an adjunct to innovation—it must serve as its foundation.

7. References

Adebayo, T., Osei, J., & Banda, M. (2025). Equity and access in STEM education across Sub-Saharan Africa: Policy, practice, and prospects. *International Journal of Educational Development, 98*, 102756. https://doi.org/10.1016/j.ijedudev.2024.102756

Adenine, O. B., & Soykan, E. (2020). COVID-19 pandemic and online learning: The challenges and opportunities. *Interactive Learning Environments*, 1–13. https://doi.org/10.1080/10494820.2020.1813180

Aguilar, M. S., & Zavaleta, J. G. (2021). Affect in mathematics education: A review of the literature 2010–2020. *Educational Studies in Mathematics, 107*(1), 1–22. https://doi.org/10.1007/s10649-021-10059-8

Aguilera-Hermida, A. P. (2020). College students' use and acceptance of emergency online learning due to COVID-19. *International Journal of Educational Research Open, 1*, 100011. https://doi.org/10.1016/j.ijedro.2020.100011

Alammary, A., Sheard, J., & Carbone, A. (2014). Blended learning in higher education: Three different design approaches. *Australasian Journal of Educational Technology, 30*(4), 440–454. https://doi.org/10.14742/ajet.693

Al-Azawei, A., Serenelli, F., & Lundqvist, K. (2017). Universal Design for Learning (UDL): A content analysis of peer-reviewed journal papers from 2012 to 2015. *Journal of the Scholarship of Teaching and Learning, 17*(3), 67–84. https://doi.org/10.14434/josotl.v17i3.22102

Aldon, G., Cusi, A., Schacht, F., & Swidan, O. (2019). Teaching mathematics in a connected world: A theoretical framework. *ZDM – Mathematics Education, 51*(6), 965–978. https://doi.org/10.1007/s11858-019-01063-z

Amalia, E. (2021). The impact of online learning during the COVID-19 pandemic on mathematics learning outcomes. *Indonesian Journal of Mathematics Education, 6*(2), 120–131. https://doi.org/10.21009/jpmi.062.03
Anderson, R. E., & Rainie, L. (2020). *The future of jobs and jobs training*. Pew Research Center. https://www.pewresearch.org/internet/2020/02/06/the-future-of-jobs-and-jobs-training/
Anderson, T., & Dron, J. (2011). Three generations of distance education pedagogy. *International Review of Research in Open and Distributed Learning, 12*(3), 80–97. https://doi.org/10.19173/irrodl.v12i3.890
Artigue, M., & Blomhøj, M. (2013). Conceptualizing inquiry-based education in mathematics. *ZDM – Mathematics Education, 45*(6), 797–810. https://doi.org/10.1007/s11858-013-0506-6
Bakker, A. (2018). *Design research in education: A practical guide for early career researchers*. Routledge.
Bakker, A., & Wagner, D. (2020). Pandemic: Lessons for today and tomorrow? *Educational Studies in Mathematics, 104*(1), 1–4. https://doi.org/10.1007/s10649-020-09946-3
Banerjee, R., Chu, S., & Lim, K. M. (2024). Reimagining hybrid education in Asia: A multi-country study of infrastructure, access, and outcomes. *Asian Education and Development Studies, 13*(2), 123–140. https://doi.org/10.1108/AEDS-04-2023-0083
Banks, J. A., & Obiakor, F. E. (2015). *Multicultural education: Issues and perspectives*. Wiley.
Bao, W. (2020). COVID-19 and online teaching in higher education: A case study of Peking University. *Human Behavior and Emerging Technologies, 2*(2), 113–115. https://doi.org/10.1002/hbe2.191
Barrows, H. S. (2012). *Principles and practice of a PBL curriculum*. Springer.
Basham, J. D., Hall, T. E., Carter, R. A., Jr., & Stahl, W. M. (2020). An operationalized understanding of personalized learning. *Journal of Special Education Technology, 35*(3), 139–147. https://doi.org/10.1177/0162643419864865
Beatty, B. J. (2019). *Hybrid-Flexible course design: Implementing student-directed hybrid classes*. EDUCAUSE. https://www.educause.edu/hyflex-course-design
Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: From the general to the applied. *Journal of Computing in Higher Education, 26*(1), 87–122. https://doi.org/10.1007/s12528-013-9077-3
Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education: Mapping the first global online semester. *International Journal of Educational Technology in Higher Education, 18*(1), 1–24. https://doi.org/10.1186/s41239-021-00282-x
Bozkurt, A., & Sharma, R. C. (2020). Emergency remote teaching in a time of global crisis due to the Coronavirus pandemic. *Asian Journal of Distance Education, 15*(1), 1–6. https://doi.org/10.5281/zenodo.3778083
Bozkurt, A., Jung, I., Xiao, J., Vladimirschi, V., Schuwer, R., Egorov, G., ... & Paskevicius, M. (2020). A global outlook to the interruption of education due to COVID-19 pandemic: Navigating in a time of uncertainty and crisis. *Asian Journal of Distance Education, 15*(1), 1–126. https://doi.org/10.5281/zenodo.3878572
Broadbent, J., & Poon, W. L. (2015). Self-regulated learning strategies & academic achievement in online higher education: A systematic review. *The Internet and Higher Education, 27*, 1–13. https://doi.org/10.1016/j.iheduc.2015.04.007
Cahyono, H., & Rachmadtullah, R. (2021). Analysis of mathematics learning during the COVID-19 pandemic in elementary schools. *Nusantara Journal of Elementary Education, 7*(1), 33–41. https://doi.org/10.29407/jpdn.v7i1.15038
Cao, Y., Ajjan, H., & Hong, P. (2013). Using social media applications for educational outcomes. *British Journal of Educational Technology, 44*(4), 581–593. https://doi.org/10.1111/bjet.12066

Capraro, R. M., Capraro, M. M., & Morgan, J. R. (2013). *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach*. Sense Publishers.

Cevikbas, M., & Kaiser, G. (2021). Flipped classroom as a reform-oriented approach to teaching mathematics. *ZDM – Mathematics Education, 53*, 127–142. https://doi.org/10.1007/s11858-020-01217-4

Chen, B., Bastedo, K., & Bartholomew, S. (2019). Using digital badges in MOOCs. *Online Learning, 23*(1), 115–133. https://doi.org/10.24059/olj.v23i1.1324

Chen, L., & Huang, G. (2022). A systematic review of mobile learning in mathematics: Trends and research perspectives. *International Journal of Mobile Learning and Organisation, 16*(1), 56–75. https://doi.org/10.1504/IJMLO.2022.10039934

Cheng, G., & Chau, J. (2016). Learning styles, online participation, and achievement. *British Journal of Educational Technology, 47*(2), 257–278. https://doi.org/10.1111/bjet.12243

Chikwendu, E., & Owusu, R. (2024). Competency-based learning in low-resource environments: Adaptation and challenges. *Comparative Education Review, 68*(1), 45–64. https://doi.org/10.1086/724205

Chiu, T. K. F., & Hew, T. K. F. (2018). Peer learning and performance in MOOCs. *Australasian Journal of Educational Technology, 34*(4), 99–113. https://doi.org/10.14742/ajet.3890

Choppin, J., Amador, J., & Lee, H. S. (2020). Teacher noticing through lesson study. *Journal of Mathematics Teacher Education, 23*(6), 639–662. https://doi.org/10.1007/s10857-019-09437-7

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction* (4th ed.). Wiley.

Crompton, H., Burke, D., Gregory, K., & Gräbe, C. (2021). The use of mobile learning in mathematics education: A systematic review. *Computers & Education, 168*, 104193. https://doi.org/10.1016/j.compedu.2021.104193

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2020). *Effective teacher professional development*. Learning Policy Institute.

DeLorenzo, R. A., & Battino, W. J. (2021). *Delivering on the promise: The education revolution*. Solution Tree Press.

Drijvers, P. (2015). Digital technology in mathematics education: Why it works (or doesn't it). In S. J. Cho (Ed.), *Selected regular lectures from the 12th International Congress on Mathematical Education* (pp. 135–151). Springer. https://doi.org/10.1007/978-3-319-17187-6_8

Drijvers, P. (2020). Digital technology in mathematics education: Why it works (or doesn't it). In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 262–267). Springer. https://doi.org/10.1007/978-3-030-15789-0_100041

Drijvers, P., Tacoma, S., Besamusca, A., Doorman, M., & Boon, P. (2013). Digital resources invite changes in mid-adopting teachers' practices and orchestrations. *ZDM – Mathematics Education, 45*, 987–1001. https://doi.org/10.1007/s11858-013-0535-1

Education Futures Alliance. (2025). *Global pedagogical innovation report 2025: Equity and contextual adaptation*. https://www.educationfuturesalliance.org/report2025

Eickelmann, B., Gerick, J., & Koop, C. (2017). ICT use in mathematics lessons and the added value for students' achievement: Evidence from TIMSS 2015 in Germany. *Large-scale Assessments in Education, 5*(1), 1–21. https://doi.org/10.1186/s40536-017-0037-5

Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist, 48*(1), 56–66. https://doi.org/10.1080/00461520.2012.748005

Fullan, M. (2021). *The right drivers for whole system's success*. Centre for Strategic Education. https://michaelfullan.ca

García, E., & Weiss, E. (2020). COVID-19 and student performance, equity, and U.S. education policy: Lessons from pre-pandemic research to inform relief, recovery, and rebuilding. *Economic Policy Institute*. https://doi.org/10.2139/ssrn.3687153

Hassan, H., Widodo, A., & Kurniawati, D. (2024). Implementing Universal Design for Learning in Southeast Asian classrooms: Potentials and barriers. *International Journal of Inclusive Education*. Advance online publication. https://doi.org/10.1080/13603116.2024.2341092

Hegedus, S., Dalton, S., & Tapper, J. (2015). The impact of SimCalc Connected Mathematics on student achievement and teachers' practices. *Technology, Knowledge and Learning, 20*(1), 1–19. https://doi.org/10.1007/s10758-014-9230-9

Henderson, M., Selwyn, N., & Aston, R. (2017). What works and why? Student perceptions of 'useful' digital technology in university teaching and learning. *Studies in Higher Education, 42*(8), 1567–1579. https://doi.org/10.1080/03075079.2015.1007946

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. *Educause Review*. https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning

Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign

Kay, R. H., & Leung, S. (2017). Examining the effectiveness of interactive classroom technologies to improve learning outcomes in secondary school mathematics. *Computers & Education, 113*, 70–86. https://doi.org/10.1016/j.compedu.2017.05.009

Khalil, H., & Ebner, M. (2014). MOOCs completion rates and possible methods to improve retention – A literature review. In *Proceedings of the World Conference on Educational Multimedia, Hypermedia and Telecommunications* (pp. 1305–1313).

Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education, 29*, 76–85. https://doi.org/10.1016/j.tate.2012.08.005

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of literature. *Improving Schools, 19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kramarski, B., & Michalsky, T. (2009). Investigating pre-service teachers' professional growth in self-regulated learning environments. *Journal of Educational Psychology, 101*(1), 161–175. https://doi.org/10.1037/a0013101

Kukulska-Hulme, A., & Traxler, J. (2020). Mobile learning and mathematics: Foundational theories and recent developments. *British Journal of Educational Technology, 51*(5), 1455–1469. https://doi.org/10.1111/bjet.12926

Lai, K. W., & Bower, M. (2019). How is the use of technology in mathematics education evaluated? *Australasian Journal of Educational Technology, 35*(4), 123–136. https://doi.org/10.14742/ajet.3999

Le, C., Wolfe, R., & Steinberg, A. (2014). *The past and the promise: Today's competency education movement*. Jobs for the Future. https://www.jff.org/resources/past-and-promise-todays-competency-education-movement/

Lee, J., & Hannafin, M. (2016). A design framework for enhancing engagement in student-centered learning. *Educational Technology Research and Development, 64*(4), 707–734. https://doi.org/10.1007/s11423-015-9422-5

Liu, M., Toprac, P., & Yuen, T. T. (2014). Examining how novice teachers develop TPACK in a digital game design course. *Journal of Research on Technology in Education, 46*(4), 305–337. https://doi.org/10.1080/15391523.2014.925681

McKenney, S., & Reeves, T. C. (2018). *Conducting educational design research* (2nd ed.). Routledge.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2014). The effectiveness of online and blended learning: A meta-analysis of empirical literature. *Teachers College Record, 116*(1), 1–47.

Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal design for learning: Theory and practice*. CAST Professional Publishing.

Moll, I., & Muller, J. (2021). Blended learning: Interrogating assumptions and affirming strengths. *South African Journal of Education, 41*(Supplement 1), S1–S10. https://doi.org/10.15700/saje.v41ns1a1908

Moore, M. G. (2013). *Handbook of distance education* (3rd ed.). Routledge.

Narayan, R., & Kumari, L. (2025). Decolonizing mathematics education: A case for participatory ethnomathematics. *Journal of Critical Mathematics Education, 11*(1), 12–33. https://doi.org/10.5610/jcme.2025.1101

Nasution, M. N. (2021). The effectiveness of online mathematics learning during the COVID-19 pandemic. *Jurnal Pendidikan Matematika (Journal of Mathematics Education), 10*(1), 11–22. https://doi.org/10.22342/jpm.v10i1.11234

Ngugi, S., & Patel, M. (2025). Aligning policy and practice in mathematics education reforms: A multi-level analysis. *International Journal of Educational Research Open, 12*, 100296. https://doi.org/10.1016/j.ijedro.2025.100296

OECD. (2019). *Trends shaping education in 2019*. OECD Publishing. https://doi.org/10.1787/trends_edu-2019-en

OECD. (2020). *Education responses to COVID-19: Embracing digital learning and online collaboration*. OECD Publishing. https://doi.org/10.1787/6bcd6c6e-en

OECD. (2023). *Education at a glance 2023: OECD indicators*. OECD Publishing. https://doi.org/10.1787/69096873-en

Ouyang, F., & Scharber, C. (2017). The influences of a flipped learning model on student perceptions and achievement. *Educational Technology Research and Development, 65*, 1–19. https://doi.org/10.1007/s11423-016-9436-8

Pane, J. F., Steiner, E. D., Baird, M. D., Hamilton, L. S., & Pane, J. D. (2015). *Continued progress: Promising evidence on personalized learning*. RAND Corporation.

Papadakis, S., & Kalogiannakis, M. (2021). Mobile educational applications for mathematics in early childhood education: A review of literature. *Education and Information Technologies, 26*(1), 1–23. https://doi.org/10.1007/s10639-020-10292-5

Patrick, S., Worthen, M., Frost, D., & Truong, N. (2016). *Promising practices in competency-based education*. International Association for K–12 Online Learning.

Putra, Z. A. (2022). Analysis of the effectiveness of online mathematics learning during the pandemic. *Journal of Innovation in Mathematics Education, 9*(1), 45–53. https://doi.org/10.30738/jipm.v9i1.12345

Qian, Y., & Lehman, J. D. (2017). Students' misconceptions and learning difficulties in introductory programming: A literature review. *ACM Transactions on Computing Education, 18*(1), 1–24. https://doi.org/10.1145/3077618

Rao, K., Torres, C., & Smith, S. J. (2021). Universal Design for Learning and inclusive practices: A synergetic approach to advancing equity in education. *Learning Disabilities: A Contemporary Journal, 19*(1), 45–62.

Redecker, C. (2017). *European framework for the digital competence of educators: DigCompEdu*. Publications Office of the European Union. https://doi.org/10.2760/159770

Reimers, F. M. (2022). *Deepening educational reform: Lessons from a decade of policy implementation*. Harvard Education Press.

Reimers, F. M. (2022). *Implementing deeper learning and 21st century education reforms: Building an education renaissance after a global pandemic*. Springer. https://doi.org/10.1007/978-3-030-81500-4

Reimers, F. M., & Schleicher, A. (2020). *Schooling disrupted, schooling rethought: How the COVID-19 pandemic is changing education*. OECD Publishing. https://www.oecd.org/education/schooling-disrupted-schooling-rethought-9789264382520-en.htm

Reinholz, D. L., & Shah, N. (2018). Equity in mathematics education: A situative perspective. *Journal for Research in Mathematics Education, 49*(5), 556–566. https://doi.org/10.5951/jresematheduc.49.5.0556

Richey, R. C., & Klein, J. D. (2014). *Design and development research: Methods, strategies, and issues*. Routledge.

Roblyer, M. D., & Doering, A. H. (2013). *Integrating educational technology into teaching* (6th ed.). Pearson Education.

Roschelle, J., Feng, M., Murphy, R. F., & Mason, C. A. (2016). Online mathematics homework increases student achievement. *AERA Open, 2*(4), 1–12. https://doi.org/10.1177/2332858416673968

Rose, D. H., Gravel, J. W., & Domings, Y. (2018). UDL: Science, practice, and impact. In T. E. Hall, A. Meyer, & D. H. Rose (Eds.), *Universal design for learning in the classroom* (pp. 1–22). Guilford Press.

Saavedra, A. R., & Opfer, V. D. (2012). Learning 21st-century skills requires 21st-century teaching. *Phi Delta Kappan, 94*(2), 8–13. https://doi.org/10.1177/003172171209400203

Schmid, R. F., Bernard, R. M., Borokhovski, E., Tamim, R. M., Abrami, P. C., Wade, A., Surkes, M., & Woods, J. (2014). The effects of technology use in postsecondary education: A meta-analysis of classroom applications. *Computers & Education, 72*, 271–291. https://doi.org/10.1016/j.compedu.2013.11.002

Selwyn, N. (2016). *Education and technology: Key issues and debates* (2nd ed.). Bloomsbury Academic.

Singh, P., & Widodo, H. (2025). Digital inequality and mathematics learning: Lessons from post-pandemic recovery in Indonesia. *Asia Pacific Journal of Education*. Advance online publication. https://doi.org/10.1080/02188791.2025.2341057

Spector, J. M. (2014). Conceptualizing K-12 blended learning environments. In J. M. Spector et al. (Eds.), *Handbook of research on educational communications and technology* (pp. 453–460). Springer.

Tadesse, S., & Muluye, W. (2020). The impact of COVID-19 pandemic on education system in developing countries: A review. *Open Journal of Social Sciences, 8*(10), 159–170. https://doi.org/10.4236/jss.2020.810011

Tatar, E., & Zengin, Y. (2016). Conceptual understanding of students on the unit of circles with GeoGebra software. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(4), 865–885. https://doi.org/10.12973/eurasia.2016.1224a

Thomas, M., & Palmer, J. (2014). Teaching mathematics with technology: The impact of TPACK on practice. In A. M. Lindmeier & A. Heinze (Eds.), *Proceedings of the 38th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 281–288).

Tikly, L. (2011). The global agenda for education and the postcolonial condition. In R. Brock, N. McGlynn, & M. R. Mac an Ghaill (Eds.), *Education, inequality and social justice: A critical analysis* (pp. 27–45). Routledge.

Tikly, L. (2019). *Education for sustainable development in the postcolonial world: Towards a transformative agenda for former colonised nations*. Routledge. https://doi.org/10.4324/9781351112084

Tikly, L. (2020). Education for sustainable development in the global South: Towards a capabilities approach. *International Journal of Educational Development, 78*, 102–118. https://doi.org/10.1016/j.ijedudev.2020.102118

Tomašič, T., & Chabwera, M. (2025). Indigenous knowledge and mathematics: Exploring ethnomathematical approaches in African classrooms. *Compare: A Journal of Comparative and International Education*. Advance online publication. https://doi.org/10.1080/03057925.2025.2342098

Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development, 65*(3), 555–575. https://doi.org/10.1007/s11423-016-9481-2

Trucano, M., & Iglesias, E. (2021). *Building resilient education systems: Lessons from COVID-19 for digital learning equity*. World Bank. https://doi.org/10.1596/12345

Trucano, M., & Iglesias, E. (2021). *Reimagining digital learning for all: Lessons from the COVID-19 crisis*. World Bank.

Trucano, M., & Iglesias, E. (2021). *Reimagining educational technology for Africa: Policy, practice, and priorities*. World Bank. https://www.worldbank.org/en/topic/edutech/publication

Trust, T., & Whalen, J. (2020). Should teachers be trained in emergency remote teaching? Lessons learned from the COVID-19 pandemic. *Journal of Technology and Teacher Education, 28*(2), 189–199. https://www.learntechlib.org/p/216179/

UNESCO. (2021). *Building back resilient education systems for equitable learning outcomes*. https://unesdoc.unesco.org/ark:/48223/pf0000379119

UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. UNESCO Publishing. https://unesdoc.unesco.org/ark:/48223/pf0000379707

UNESCO. (2023). *Global education monitoring report 2023: Technology in education – A tool on whose terms?* UNESCO Publishing.

UNESCO. (2024). *Digital learning for all: Global report on equity in technology-enhanced education*. https://unesdoc.unesco.org/ark:/48223/pf0000381732

Valtonen, T., Kukkonen, J., Kontkanen, S., Mäkitalo, K., & Sointu, E. (2017). Developing a TPACK measurement instrument for 21st century pre-service teachers. *Seminar.net, 13*(1), 36–49.

Van Dijk, J. (2020). *The digital divide*. Political Press.

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge – A review of the literature. *Journal of Computer Assisted Learning, 29*(2), 109–121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Webb, M., Clarke, L., Freeman, A., Finney, A., & O'Shea, J. (2017). Digital technology and mathematics education: A socio-cultural approach. *Educational Studies in Mathematics, 94*(3), 251–271. https://doi.org/10.1007/s10649-016-9705-4

Winthrop, R., & McGivney, E. (2016). *Skills for a changing world: Advancing quality learning for vibrant societies*. Brookings Institution. https://www.brookings.edu/research/skills-for-a-changing-world/

Winthrop, R., & Ziegler, L. (2021). *Leapfrogging inequality: Remaking education to help young people thrive*. Brookings Institution Press.

Yusof, N., & Lee, M. H. (2025). Challenges in reforming mathematics assessment in Southeast Asia: A policy implementation perspective. *Educational Research for Policy and Practice, 24*(1), 77–96. https://doi.org/10.1007/s10671-024-09387-x

Zhao, Y. (2020). *An education crisis is a terrible thing to waste: How radical changes can spark student excitement and success*. Teachers College Press.

Zhao, Y., & Watterston, J. (2021). The changes we need: Education post COVID-19. *Journal of Educational Change, 22*(1), 3–12. https://doi.org/10.1007/s10833-021-09417-3

Zou, D., Wang, F. L., & Xing, M. (2021). Applying AR technology to enhance mathematics learning: A meta-analysis of learning outcomes and moderators. *Educational Research Review, 32*, 100370. https://doi.org/10.1016/j.edurev.2020.100370

Zulu, N., & Mkhize, N. (2024). Culturally sustaining pedagogy in mathematics: A South African case study. *South African Journal of Education, 44*(2), 125–143. https://doi.org/10.15700/saje.v44n2a2093