Technological Innovations and Artificial Intelligence Integration in English-Medium Mathematics Instruction: A Systematic Review

Noraida Md Idrus, Nurfaradilla Mohamad Nasri and Muhammad Sofwan Mahmud

Abstract – **The rapid advancement of Artificial Intelligence (AI) and digital technologies has transformed educational practices globally. It particularly include in English-medium mathematics instruction where linguistic diversity and cognitive complexity intersect. Despite this growing interest, research remains fragmented regarding how AI-driven pedagogies and technological innovations support mathematics instruction for non-native English speakers. This study conducts a Systematic Literature Review (SLR) guided by the PRISMA protocol to synthesise existing evidence from the Scopus and Web of Science databases. A total of 22 empirical studies were selected after applying rigorous identifying, screening and eligibility criteria. Thematic analysis revealed three dominant areas of focus: (1) Translanguaging and Language-Based Pedagogies in English-medium Instruction (EMI) Mathematics and STEM Contexts, emphasising the role of multilingual strategies and language mediation in AI-assisted learning; (2) Policy, Identity and Teacher Beliefs in English-medium and Content and Language Integrated Learning (CLIL) Frameworks, highlighting educators' perceptions, institutional challenges and pedagogical adaptations; and (3) Technological Innovation, AI and Digital Pedagogies in EMI Teaching and Learning, exploring the integration of intelligent tools, digital platforms and adaptive systems that enhance engagement and comprehension. The findings demonstrate that AI and technology integration facilitate inclusive, data-informed and interactive mathematics learning environments while underscoring persistent gaps in teacher readiness and policy alignment. This review contributes to advancing theoretical and practical understanding of AI-enhanced English-medium mathematics instruction and provides implications for future research, curriculum design and professional development in multilingual education systems.**

Keywords – **Artificial Intelligence, Digital Pedagogies, English-medium, Mathematics Instruction, PRISMA**

I. INTRODUCTION

The intersection of English-medium mathematics instruction and artificial intelligence (AI) has emerged as a significant focus in educational discourse, particularly within developed contexts where multilingual classrooms are increasingly common. English-medium instruction (EMI) in mathematics requires learners to process mathematical content delivered in English, even when their home languages differ, creating an additional layer of linguistic complexity. Studies have documented that non-native English learner frequently encounter difficulties with academic vocabulary, complex word problems and language-heavy mathematical explanations, all of which shape how they interpret mathematical ideas and ultimately influence performance (Robertson & Graven, 2020). Against this backdrop, artificial intelligence represented through adaptive tutoring systems, intelligent feedback tools and conversational agents has gained attention for its capacity to personalise instruction while supporting both language development and content comprehension. AI-driven scaffolding coupled with real-time feedback, holds potential to reduce barriers in mathematics learning for students navigating dual linguistic and cognitive demands. Research further highlights that successful AI implementation depends heavily on teachers' technological pedagogical content knowledge (TPACK) competencies and institutional readiness (M. Li, 2025), underscoring the need for a holistic understanding of technology integration in EMI mathematics contexts.

Given the increasing emphasis on multilingual learning environments and the rapid uptake of digital innovation in education, examining the combined role of EMI and AI in mathematics learning has become particularly relevant. This area of inquiry offers promising insights for educators, curriculum developers and policymakers seeking to enhance equity in mathematics classrooms by addressing the linguistic constraints experienced by non-native speakers. Integrating AI-supported language scaffolds into mathematics instruction offers opportunities to strengthen students' comprehension of mathematical discourse while simultaneously enhancing their English proficiency. Such a dual-support approach positions AI as a strategic tool for transforming mathematics learning in linguistically diverse settings. As a result, situating this investigation at the intersection of language, content and technology presents an important step toward improving instructional design, supporting learner diversity and informing future educational models for multilingual classrooms.

II. PROBLEM STATEMENT

Although EMI and AI each contribute valuable dimensions to the learning experience, existing scholarship reveals several gaps when these two domains intersect within mathematics education for non-native English speakers. Research consistently points to the relationship between English proficiency and mathematics performance in EMI settings (Taifour & Alabdulaziz, 2025), yet few studies extend this understanding to include AI-mediated scaffolding. Much of the AI-in-education

Noraida Md Idrus, National University of Malaysia, Malaysia (Email: noraida.mdidrus@gmail.com)
Nurfaradilla Mohamad Nasri, National University of Malaysia, Malaysia (Email: nurfaradilla@ukm.edu.my)
Muhammad Sofwan Mahmud, National University of Malaysia, Malaysia (Email: sofwanmahmud@ukm.edu.my)

literature continues to treat language learning and mathematics learning as parallel but separate fields, leaving limited evidence regarding how these domains interact in real multilingual classrooms. Studies exploring AI conversational agents, for instance, often focus exclusively on English-as-a-Second-Language instruction without assessing their relevance to mathematics learning or examining how they function specifically within English-medium educational settings (Dai & Wu, 2025). This narrow focus highlights a missed opportunity to explore how AI might support the simultaneous development of linguistic comprehension and mathematical reasoning.

Another unresolved challenge lies in the scarcity of empirical research that investigates the combined linguistic and cognitive demands faced by non-native English learners in AI-mediated EMI mathematics classrooms. Existing work rarely examines how AI tools influence mathematical meaning-making, engagement in classroom discourse or participation in problem-solving when instruction is delivered in English. There is also insufficient evidence concerning how AI-supported pedagogical approaches might help students navigate mathematics vocabulary, syntactic complexity and discipline-specific discourse patterns. Furthermore, broader systemic and contextual factors including teacher preparedness, policy constraints and CLIL-related identity negotiations remain underexplored despite their strong influence on AI integration in EMI environments. Addressing these gaps is essential for building a more coherent understanding of how AI can enhance learning outcomes for non-native English speakers in English-medium mathematics instruction and for guiding future curriculum development and classroom innovation.

The study therefore adopts the following research questions, developed using the PICo (Population, Interest, Context) framework (Lockwood et al., 2015):

1. How do translanguaging strategies and AI-mediated language supports affect mathematical understanding, classroom discourse and learner engagement among non-native English-speaking students in English-medium mathematics and STEM settings?
2. In what ways do EMI/CLIL policy environments and teacher identity negotiations shape STEM teachers' readiness, beliefs and professional development needs for integrating AI-enabled language-support and pedagogical innovations in English-medium instruction?
3. What are the pedagogical affordances, measurable learning effects, equity concerns and scalability constraints of AI-driven and digital pedagogies used in English-medium mathematics instruction for non-native English learners?

III. LITERATURE REVIEW

The integration of AI into English-medium mathematics instruction for non-native speakers has gained increasing scholarly attention. Studies highlight AI's transformative role in overcoming linguistic and cognitive barriers within multilingual learning contexts (Li et al., 2025; Zakaria et al., 2024; Zhou, 2023). Recent trends show a move from theoretical discussions to empirical validation, where AI tools such as generative models, intelligent tutoring systems and learning analytics demonstrate strong pedagogical potential. Li et al. (2025) reported that generative AI achieved human-comparable scoring precision in English and Mathematics, while Zhou (2023) noted performance gains of 22.9% in Mathematics and 14.7% in English. Similarly, Zakaria et al. (2024) highlighted AI's cross-disciplinary value in enhancing both subject comprehension and language proficiency.

Constructivist frameworks underpin many AI-based pedagogical models. Eyal & Hayak (2025) incorporated digital game-based learning into teacher training, while Zapata-Rivera et al. (2009) integrated assessment and learning through AI-supported educational gaming. These approaches encourage active learning and adaptive feedback but require greater teacher digital literacy and institutional support. AI-driven language learning applications also show promise. Sun (2023) used fuzzy decision systems to improve English speaking instruction; Jing et al. (2022) developed AI-based pronunciation evaluation; and Sun et al. (2021) employed decision tree algorithms for individualised online teaching. However, integration into mathematics contexts remains limited.

In mathematics education, Cooper et al. (2024) and Gonzalez-Nucamendi et al. (2023) demonstrated AI's capacity to support multilingual learners and predict at-risk students, while Zhou (2023) provided quantitative evidence of performance improvement. Broader implications include sustainability and emotional well-being (Guo, 2023; Uğraş et al., 2024), as well as concerns about algorithmic bias Prates et al. (2020). Despite substantial progress, existing research tends to separate linguistic and mathematical learning. Future inquiry should focus on hybrid frameworks that combine linguistic scaffolding, adaptive feedback and culturally responsive AI tools to enhance English-medium mathematics instruction for diverse learners.

IV. METHOD

To conduct this systematic literature review (SLR), the study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework developed by Page et al. (2021) as the guiding structure. The PRISMA framework provides a rigorous and transparent process for identifying, screening and synthesising research evidence, thereby reducing bias and enhancing the credibility of findings. To ensure comprehensive coverage of relevant studies, two major and reputable academic databases, Scopus and Web of Science (WoS) were utilised as primary sources. The PRISMA procedure consists of four sequential stages: identification, screening, eligibility and data abstraction which together ensure the systematic organisation and evaluation of research evidence. Refer Figure 1.

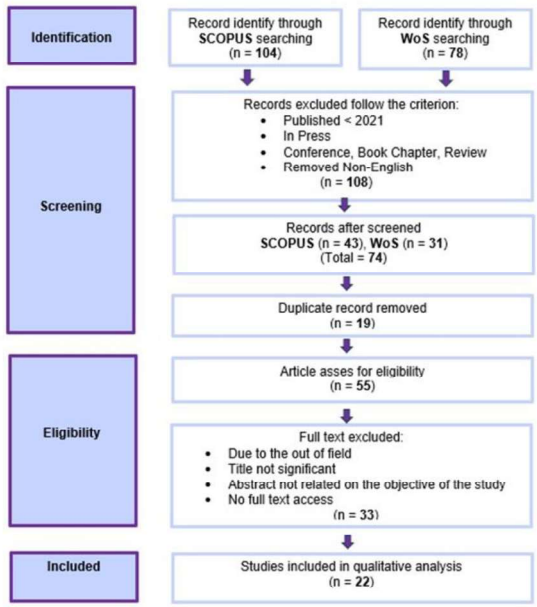

Figure 1. Flow Diagram Of The Proposed Searching Study

Participants

For the purpose of this review, the term "participants" refers to the peer-reviewed journal articles that served as the primary sources of data. An initial search across two established databases, Scopus (104) and Web of Science (78) yielded a total of 182 records. These results were then subjected to a systematic screening process to eliminate duplicates and exclude studies that were either irrelevant or did not meet the quality standards set for inclusion. After applying the inclusion and exclusion criteria, 55 distinct articles were retained. A further assessment based on thematic alignment and full-text accessibility led to the final selection of 22 articles for qualitative synthesis. The breakdown of articles by source is presented in Table One.

TABLE I: DETAILS OF PRIMARY STUDIES DATABASE

PRIMARY STUDY	TITLE	YEAR	JOURNAL	SCOPUS	WoS
PS1	Forging CLIL Teacher Identities in Kazakhstan: Developmental Pathways of Two University Teachers	2025	Chinese Journal of Applied Linguistics	/	/
PS2	From policy dumping to a participatory framework: re-envisioning the English medium instruction policy in Kazakhstan's mainstream schools	2025	Asian Englishes	/	/
PS3	Teachers' Perspectives on English Medium Instruction (EMI) in Saudi University STEM Programmes	2025	International Journal of Engineering Education	/	/
PS4	The influence of the fourth industrial revolution in teaching and learning: the COVID-19 context	2025	F1000Research	/	
PS5	Compiling data for investigating language use in classroom discourse: A corpus-driven method	2024	MethodsX	/	/
PS6	Understanding English medium instruction (EMI) policy from the perspectives of STEM content teachers in Kazakhstan	2024	TESOL Journal	/	/
PS7	The affordances of iPad for constructing a technology-mediated space in Hong Kong English medium instruction secondary classrooms: A translanguaging view	2024	Language Teaching Research	/	/
PS8	Classroom interactional competence in an English medium instruction mathematics classroom: A creation of a technology-mediated translanguaging space	2024	Learning and Instruction	/	/
PS9	The use of ICT in learning ESP by pre-service teachers of Mathematics in the wartime	2024	Texto Livre	/	/
PS10	Impostor Phenomenon Among Hispanic/Latino Early Career Researchers in STEM Fields	2024	Journal of Latinos and Education	/	/
PS11	Creating translanguaging spaces in a Hong Kong English medium instruction mathematics classroom: A comparative	2023	Linguistics and Education	/	/

	analysis of classroom interactions with and without the use of iPad				
PS12	Children's Language-Based Pedagogical Preferences in a Multilingual Society	2023	Journal of Experimental Psychology: General	/	/
PS13	High School Students' Use of Information, Media, and Technology Skills and Multidimensional 21st-Century Skills: An Investigation within the Context of Students, Teachers, and Curricula	2023	Sustainability (Switzerland)	/	/
PS14	EMI Teachers' perceptions and practices regarding culture teaching in Chinese higher education	2023	Language, Culture and Curriculum	/	/
PS15	College English Teaching Platform Optimization under Cross-Media and Mobile Internet Environment	2022	Computational Intelligence and Neuroscience	/	/
PS16	English Medium university STEM teachers' and students' ideologies in constructing content knowledge through translanguaging	2022	International Journal of Bilingual Education and Bilingualism	/	/
PS17	English-medium instruction in higher education and the ELT gaze: STEM lecturers' self-positioning as NOT English language teachers	2022	International Journal of Bilingual Education and Bilingualism	/	
PS18	Emergent STEM lecturer identities: The shaping effects of EMI in action in an internationalised and Englishised HE context	2021	Language Teaching	/	/
PS19	Network analysis of social awareness of media education for primary school students studied through big data	2021	Computer Science and Information Systems	/	/
PS20	I knew I had Issues with my Maths, but I Never Thought it could be Because of the Language: Student Success in Mathematics	2025	International Journal of Science and Mathematics Education		/
	Using Home Languages and Educational Technology				
PS21	Translanguaging and transknowledging practices among STEM teachers in EMI higher education	2025	Applied Linguistics Review		/
PS22	Advancing CLIL Approaches in EMI Settings Through International Collaboration: An Introduction	2025	Chinese Journal of Applied Linguistics		/

Instruments

To ensure the review process was systematic and replicable, several established tools and frameworks were applied. A carefully constructed search string using Boolean operators was designed to capture relevant studies from each selected database. The search strategy combined key terms such as "Mathematics Teaching", "Mathematics Education", "Mathematics Instruction", "Artificial Intelligence", "Digital", "Technology" and "English medium" to maximise retrieval accuracy. The specific search strings applied to each database are outlined in Table Two.

TABLE II: THE SEARCH STRING

DATABASE	SEARCH STRING
SCOPUS	TITLE-ABS-KEY (((Mathematics Teaching) OR (Mathematics Learning) OR (Mathematics Teaching AND Learning) OR (Mathematics Classroom) OR (Mathematics Education) OR (Mathematics Instruction)) AND ((Artificial Intelligence) OR (Internet of Thing) OR (Big Data) OR Digital OR Technology) AND (English medium)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English")) Date of Access: November 2025
WoS	(((Mathematics Teaching) OR (Mathematics Learning) OR (Mathematics Teaching AND Learning) OR (Mathematics Classroom) OR (Mathematics Education) OR (Mathematics Instruction)) AND ((Artificial Intelligence) OR (Internet of Thing) OR (Big Data) OR Digital OR Technology) AND (English medium)) (Topic) and 2025 or 2024 or 2023 or 2022 or 2021 (Publication Years) and Article (Document Types) and English Date of Access: November 2025

To identify the studies suitable for the final analysis, a set of predefined selection criteria was established before the screening process began. These criteria considered factors such as publication year, language of publication, document type and relevance to the research theme. A detailed summary of the inclusion and exclusion parameters is presented in Table Three.

TABLE III: THE SELECTION CRITERION IN SEARCHING

CRITERION	INCLUSION	EXCLUSION
Language	English	Non-English
Timeline	2021 – 2025	< 2021
Literature Type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

To maintain research quality and minimise potential bias, each selected article was evaluated using a six-criterion assessment framework adapted from Abouzahra et al. (2020). The evaluation criteria (QA1 - QA6) covered key aspects such as: (1) clarity of purpose; (2) relevance and applicability; (3) methodological rigor; (4) conceptual definition; (5) comparative depth; and (6) recognition of study limitations. Each criterion was rated on a three-point scale: "Yes" (1 point) for full compliance, "Partly" (0.5 points) for partial fulfillment with minor gaps and "No" (0 points) for non-fulfillment.

Two reviewers conducted independent assessments and later reconciled any discrepancies through discussion to ensure consistency and objectivity. This systematic evaluation functioned as a bias control measure, enhancing the reliability of the review process. The quality scores for each study are provided in Table Four and only a summary reference is made in the main text.

TABLE IV: QUALITY ASSESSMENT OF SELECTED STUDIES BASED ON SYSTEMATIC REVIEW CRITERIA (QA1–QA6)

PRIMARY STUDY	QA1	QA2	QA3	QA4	QA5	QA6	TOTAL MARK	PERCENTAGE (%)
PS1	1	1	1	1	0.5	0.5	5.0	83.3
PS2	1	1	1	1	1	0.5	5.5	91.7
PS3	1	1	1	1	1	1	6.0	100
PS4	1	1	1	1	0.5	0.5	5.0	83.3
PS5	1	1	1	1	0.5	1	5.5	91.7
PS6	1	1	1	1	1	1	6.0	100
PS7	1	1	1	1	1	0.5	5.5	91.7
PS8	1	1	1	1	0.5	0.5	5.0	83.3
PS9	1	1	1	1	0.5	0.5	5.0	83.3
PS10	1	1	1	1	0.5	0.5	5.0	83.3
PS11	1	1	1	1	0.5	0.5	5.0	83.3
PS12	1	1	1	1	1	0.5	5.5	91.7
PS13	1	1	1	1	0.5	0.5	5.0	83.3
PS14	1	1	1	1	0.5	0.5	5.0	83.3
PS15	1	1	0.5	0.5	0.5	0	3.5	58.3
PS16	1	1	1	1	0.5	0.5	5.0	83.3
PS17	1	1	1	1	1	0.5	5.5	91.7
PS18	1	1	1	1	0.5	.5	5.0	83.3
PS19	1	1	1	0.5	0.5	0.5	4.5	75
PS20	1	1	1	1	0.5	0.5	5.0	83.3
PS21	1	1	0.5	0.5	0.5	0	3.5	58.3
PS22	1	1	1	1	1	0.5	5.5	91.7

Procedures

The review process followed four systematic phases in accordance with the PRISMA protocol: identification, screening, eligibility and inclusion. In the identification phase, comprehensive database searches were conducted using the predefined search strings with all searches completed in November 2025. The screening phase involved removing duplicate records and conducting a preliminary review of titles and abstracts to filter out studies that did not meet the inclusion parameters. During the eligibility phase, full-text articles were retrieved and thoroughly examined to confirm their relevance to the integration of artificial intelligence in English-medium mathematics instruction. Studies lacking empirical grounding, theoretical value or full-text availability were excluded at this stage. The inclusion phase finalised the selection of 22 eligible studies, from which essential information was extracted. Their findings were systematically synthesised and categorised into thematic clusters that subsequently guided the analysis and discussion of this review.

V. FINDINGS

This review examined 22 peer-reviewed studies published between 2021 and 2025, all focusing on the integration of artificial intelligence within English-medium mathematics instruction. Through thematic synthesis, three central themes were identified: (1) translanguaging and language-based pedagogies in EMI Mathematics and STEM Contexts; (2) policy, identity and teacher beliefs in English-medium and CLIL frameworks; and (3) technological innovation, AI and digital pedagogies in EMI teaching and learning. The primary studies corresponding to each thematic domain is presented in Table Five.

TABLE V: THEMATIC CLASSIFICATION OF STUDIES

THEME	PRIMARY STUDY	TITLE
Translanguaging and Language-Based Pedagogies in EMI Mathematics and STEM Contexts	PS8	Classroom interactional competence in an EMI mathematics classroom
	PS11	Creating translanguaging spaces in a Hong Kong EMI mathematics classroom
	PS12	Children's Language-Based Pedagogical Preferences in a Multilingual Society
	PS16	English Medium University STEM Teachers' and Students' Ideologies in Constructing Content Knowledge through Translanguaging
	PS20	I knew I had Issues with my Maths, but I Never Thought it could be Because of the Language: Student Success in Mathematics Using Home Languages and Educational Technology
	PS21	Translanguaging and transknowledging practices among STEM teachers in EMI higher education
Policy, Identity, and Teacher Beliefs in English-Medium and CLIL	PS1	Forging CLIL Teacher Identities in Kazakhstan
	PS2	From Policy Dumping to a Participatory Framework
	PS3	Teachers' Perspectives on

Frameworks		EMI in Saudi University STEM Programmes
	PS6	Understanding EMI Policy from the Perspectives of STEM Teachers in Kazakhstan
	PS14	EMI Teachers' perceptions and practices regarding culture teaching in Chinese higher education
	PS17	English-Medium Instruction in Higher Education and the ELT Gaze
	PS18	Emergent STEM Lecturer Identities: The Shaping Effects of EMI in Action
	PS22	Advancing CLIL Approaches in EMI Settings Through International Collaboration: An Introduction
Technological Innovation, AI, and Digital Pedagogies in EMI Teaching and Learning	PS4	The Influence of the Fourth Industrial Revolution in Teaching and Learning
	PS5	Compiling Data for Investigating Language Use in Classroom Discourse
	PS7	The Affordances of iPad for Constructing a Technology-Mediated Space
	PS9	The use of ICT in learning ESP by pre-service teachers of Mathematics in the wartime
	PS10	Impostor Phenomenon Among Hispanic/Latino Early Career Researchers in STEM Fields
	PS13	High School Students' Use of Information, Media, and Technology Skills
	PS15	College English Teaching Platform Optimization under Cross-Media and Mobile Internet Environment
	PS19	Network Analysis of Social Awareness of Media Education for Primary School Students Studied through Big Data

Translanguaging and Language-based Pedagogies in EMI Mathematics and STEM Contexts

Translanguaging practices significantly improve comprehension and engagement in mathematics learning when instruction acknowledges learners' linguistic repertoires. Bonney et al. (2025) report that Ghanaian learners achieved measurable gains after using an app delivering mathematics in a home language with learners describing increased clarity, motivation and confidence. Rahman & Manjet (2022) document how purposeful translanguaging supports knowledge construction in university STEM classrooms, revealing misalignment between top-down English-only policy and classroom practice. Bashyam et al. (2023) show that children in multilingual contexts selectively prefer English speakers for STEM content but that native-language familiarity moderates this bias, implying that language choice interacts with learning goals and content type. These findings suggest that integrating home languages into mathematics instruction including through digital means can reduce linguistic barriers. It also foster cognitive access to mathematical concepts while also shaping learner affect and preferences.

Evidence emphasises the affordances of technology in creating translanguaging-friendly instructional spaces and mediating multimodal interaction. Tai (2024) demonstrates that use of mobile devices such as iPads expands teachers' multimodal repertoires and enables the orchestration of translanguaging resources to scaffold academic language and mathematical reasoning. This is related to comparative work by Tai (2023) that finds the technology-mediated translanguaging practices persist even when devices fail, indicating durable pedagogical strategies. Gu et al. (2025) identify diverse translanguaging and transknowledging tactics among STEM teachers in higher education, showing how teachers leverage multilingual semiotics and digital resources to recalibrate epistemic frameworks for knowledge co-construction. Bonney et al. (2025) further indicate that culturally and linguistically aligned educational apps can substitute for scarce policy support by offering personalised and non-judgmental practice environments. This implicates that technological tool function as both mediators and amplifiers of translanguaging pedagogy, contingent upon teacher competence and contextual adaptation.

Despite promising outcomes, the studies reveal persisting gaps concerning scalability, longitudinal impact and teacher preparation for translanguaging-oriented instruction. Rahman & Manjet (2022) and Gu et al. (2025) highlight the tension between institutional EMI policies and classroom translanguaging practices, suggesting need for participatory policy reform and professional development that recognises translanguaging as epistemic resource. Tai (2023, 2024) underscores the centrality of teacher interactional competence in technology-mediated spaces, yet the results do not quantify long-term learning gains or specify assessment protocols for combined linguistic and mathematical outcomes. Bonney et al. (2025) point to positive case outcomes with home-language apps but note contextual constraints where policy resists language policy change. Bashyam et al. (2023) indicate that learner preferences vary by age and content, implying that adaptive designs must consider developmental and sociolinguistic factors. Future research should pursue longitudinal, mixed-methods studies that measure both language development and mathematical reasoning, evaluate teacher training models and test policy interventions that legitimise translanguaging in EMI mathematics.

Policy, Identity and Teacher Beliefs in English-medium and CLIL Frameworks

Recent studies consistently identify top-down EMI policy design and implementation as a principal barrier to effective classroom practice. Manan et al. (2025) characterise policy implementation in Kazakhstan as "policy dumping" whereby responsibility for language reform is shifted onto teachers without commensurate resources or participation, producing disjunction between policy intent and classroom reality. Complementary evidence from Manan & Hajar (2024) indicates that STEM content teachers frequently experience role conflict and professional disinvestment when required to act as de facto English instructors, which undermines pedagogical confidence and fidelity to content goals. De Costa et al. (2025) argue for dialogic, collaborative international partnerships (Project SCILLA) as a pathway to reconciling national EMI mandates with local capacities, recommending deliberative policy design that includes teacher training and contextual adaptation. Abdel Latif & Alrashed (2025) further document dissatisfaction among Saudi STEM faculty regarding students' English proficiency and assessment practices, suggesting that policy reform must attend to assessment and instructional infrastructures as well as language support.

Teacher identity construction emerges as a central factor with multiple studies describing complex processes by which STEM lecturers negotiate disciplinary, linguistic and pedagogical selves. Montgomery et al. (2025) trace developmental trajectories of two university teachers forging CLIL identities, showing how prior disciplinary expertise and language histories enable or constrain CLIL enactment. Block (2021) and Block & Moncada-Comas (2022) present converging case evidence that many STEM lecturers resist being positioned as English-language teachers, instead asserting subject-specialist identities. This resistance influences classroom choices, assessment practices and collaboration with language specialists. Huang & Fang (2023) identify disciplinary differences in willingness to incorporate cultural or language-sensitive instruction with humanities lecturers more inclined than STEM colleagues to adopt explicit cultural teaching. Together, these studies indicate that identity work, shaped by institutional expectations, prior language learning and professional socialisation mediates how EMI policies translate into classroom practice.

Collective implications from the studies point toward actionable priorities. Professional development tailored to CLIL/EMI realities, participatory policymaking and integrative teacher education that addresses both language and content pedagogies. De Costa et al. (2025) and Montgomery et al. (2025) advocate international collaboration and scaffolded CLIL workshops to build teacher competence and collegial networks. Manan et al. (2025) recommend participatory policy frameworks that restore teacher agency and localised decision-making while Abdel Latif & Alrashed (2025) call for reforms in language instruction, use and assessment to sustain EMI STEM programmes. Huang & Fang (2023) suggest that teacher training should explicitly address cultural instruction and codeswitching strategies to make EMI classrooms more inclusive. Overall, the findings imply that policy, identity and pedagogy must be aligned through systemic support which are curricular, institutional and professional to enable effective English-medium mathematics and STEM instruction.

Technological Innovation, AI and Digital Pedagogies in EMI Teaching and Learning

Relevant studies indicate accelerating deployment of digital and AI-inflected tools to mediate English-medium mathematics and STEM instruction with consistent reports of improved access and instructional flexibility. Mudau & Sikhosana (2025) describe how Fourth Industrial Revolution technologies enabled alternative teaching modalities during COVID-19 but also exposed infrastructural deficits that limited equitable uptake. Tai & Wei (2024) evidence how mobile devices notably iPads, extend semiotic repertoires and create technology-mediated translanguaging spaces that support both academic language and mathematical sense-making. Leung et al. (2024) present methods for compiling longitudinal bilingual classroom corpora, enabling systematic analysis of multimodal classroom discourse facilitated by digital recording and analysis workflows. These studies foreground the pedagogical affordances of digital devices and data infrastructures for English-medium mathematics while also documenting context-sensitive constraints that shape implementation outcomes.

Methodological innovation emphasises on multimodal conversation analysis, corpus compilation, experimental ICT training and big-data network techniques. Tai & Wei (2024) combine Multimodal Conversation Analysis with video-stimulated recall to trace interactional competence in iPad-mediated lessons while Leung et al. (2024) detail procedural steps for building longitudinal bilingual corpora useful for discourse and intervention research. Previously, Jeong & Kim (2021) employ semantic network and CONCOR analyses on large public datasets to map social discourse about media education. Dmitrenko et al. (2024) report quasi-experimental verification that virtual resources raise pre-service teachers' ESP competence even under wartime constraints. These methodological patterns suggest a move toward richer, mixed-method designs that integrate qualitative interactional detail with quantitative and scalable analytics.

Persistent challenges emerge concerning equity, skill readiness and assessment alignment when integrating technology into EMI mathematics. Mudau & Sikhosana (2025) highlight digital-divide issues in which limited internet and hardware undermine intended benefits, while Hürsen et al. (2023) report insufficient development of problem-solving and programming skills despite moderate digital literacy, indicating curriculum and classroom practices lag behind technological expectations. Wang (2022) proposes platform optimisation and smart-classroom design but studies indicate scant empirical testing of large-scale implementations. Jeong & Kim (2021) infer that societal readiness and policy direction

influence the scope of media education. Consequently, digital solutions require parallel investment in infrastructure, teacher professional development and curriculum redesign to translate technological affordances into sustained learning gains.

Implications for future research and practice emphasise longitudinal evaluation, teacher capacity building and culturally attuned design of AI-mediated tools. Dmitrenko et al. (2024) recommend sustained experimental and follow-up studies to confirm durability of ESP gains from ICT training. Tai & Wei (2024) suggest that teacher interactional competence must be foregrounded in any technology integration strategy, while Leung et al. (2024) offer corpus resources as a basis for adaptive pedagogical analytics. Hürsen et al. (2023) call for curriculum adjustments that explicitly cultivate problem-solving and programming abilities alongside communication skills. Research agendas should therefore combine infrastructural studies, longitudinal learning-outcome evaluations and design research that co-produces AI-enabled resources with teachers and learners in their sociocultural contexts.

VI. DISCUSSION

The findings from this systematic review provide an integrative understanding of how technological innovations and artificial intelligence (AI) are transforming English-medium mathematics instruction, particularly for non-native speakers of English. The analysis of twenty-two peer-reviewed studies published between 2021 and 2025 revealed three overarching themes that collectively illuminate the dynamic interaction between language, technology and pedagogy in multilingual educational contexts: (1) Translanguaging and Language-Based Pedagogies in EMI Mathematics and STEM Contexts, (2) Policy, Identity, and Teacher Beliefs in English-Medium and CLIL Frameworks, and (3) Technological Innovation, AI and Digital Pedagogies in EMI Teaching and Learning. The synthesis underscores that while AI-driven tools and digital innovations significantly enhance instructional accessibility, their effectiveness largely depends on institutional policy support, teacher readiness and alignment with students' linguistic repertoires. The review also confirms a global shift from traditional English-only pedagogies toward more inclusive, multimodal and technology-mediated frameworks that bridge linguistic and disciplinary divides. However, persistent gaps remain in scaling translanguaging practices, sustaining teacher professional development and establishing ethical and infrastructural standards for AI deployment in education.

The first major theme highlights how multilingual pedagogies supported by technology can mitigate linguistic barriers and enhance students' comprehension of mathematical concepts. Across multiple studies (Bashyam et al., 2023; Bonney et al., 2025; Gu et al., 2025; Rahman & Manjet, 2022; Tai, 2024), translanguaging practices were shown to facilitate sense-making by allowing learners to draw upon their home languages and cultural knowledge during mathematical reasoning. The use of mobile and digital tools such as iPads and culturally responsive learning applications enabled teachers to create multimodal spaces where language and mathematics interact meaningfully. For instance, Tai (2024) and Gu et al. (2025) found that translanguaging through digital mediation promoted active learning and improved academic discourse. However, the review identifies limitations related to scalability, teacher preparedness and long-term learning assessment. Institutional resistance to translanguaging remains a critical barrier, as EMI policies in many systems continue to privilege monolingual English instruction, often undermining teachers' capacity to adapt lessons to students' linguistic needs. These findings suggest that language-based pedagogical flexibility, supported by AI translation and voice-recognition technologies, could enable more inclusive EMI mathematics environments. Future studies should therefore investigate longitudinal impacts of AI-mediated translanguaging and develop hybrid language-pedagogy models that explicitly integrate linguistic scaffolding with mathematical problem-solving.

The second theme addresses systemic and human factors influencing the success of AI and EMI integration. The reviewed studies (Abdel Latif & Alrashed, 2025; Block, 2021; De Costa et al., 2025; Huang & Fang, 2023; Manan et al., 2025; Montgomery et al., 2025) consistently reveal tensions between top-down language policy and teachers' professional identities. Many STEM educators in EMI contexts experience a dual burden, delivering content while simultaneously teaching in a non-native language leading to role conflict and reduced pedagogical confidence. Teachers often resist being perceived as English-language instructors, which affects their engagement with language-sensitive strategies and technology-assisted interventions. De Costa et al. (2025) and Manan et al. (2025)) highlight that the success of EMI implementation relies on participatory policymaking that acknowledges teachers as co-constructors of reform rather than passive implementers. Moreover, identity negotiation plays a central role in determining how instructors adopt AI technologies; those with strong disciplinary and linguistic self-efficacy are more likely to integrate AI tools meaningfully. This theme underscores the necessity of aligning teacher education with AI integration, emphasising technological, pedagogical and linguistic competence. Policy reforms should encourage institutional collaboration between language and STEM faculties, promote AI-informed CLIL frameworks, and establish professional development programs that equip educators to navigate the complexities of EMI instruction. Without structural and professional alignment, AI tools risk being underutilised or misapplied, perpetuating inequities rather than alleviating them.

The third theme demonstrates a growing body of evidence supporting the pedagogical value of intelligent technologies and digital infrastructures in mathematics education. Studies such as Tai & Wei (2024), Leung et al. (2024), Mudau & Sikhosana (2025) and Dmitrenko et al. (2024) document how AI and digital devices expand multimodal communication, enhance learner engagement and foster real-time feedback mechanisms that adapt to

individual linguistic and cognitive needs. AI-powered learning environments enable multilingual learners to visualise mathematical concepts, access bilingual resources and receive immediate corrective feedback. Furthermore, corpus-based analyses and multimodal conversation methodologies (Leung et al., 2024) illustrate how AI can systematise research on bilingual discourse in STEM classrooms, offering new insights into how language mediates cognition. Nevertheless, challenges persist regarding digital inequity, algorithmic bias and limited teacher capacity to interpret AI-generated data effectively. Mudau & Sikhosana (2025) point out that inadequate infrastructure and uneven internet access undermine AI adoption in developing contexts, while Hürsen et al. (2023) and Wang (2022) emphasise the need for curriculum redesign to incorporate computational thinking and digital literacy. Thus, although AI integration holds substantial potential for enhancing learning, its success depends on sustainable investment in technological infrastructure, ethical data governance and teacher professional development that emphasises critical digital pedagogy.

From a broader interpretive perspective, these three themes collectively indicate that successful integration of AI into English-medium mathematics instruction requires a triadic balance between linguistic inclusivity, pedagogical innovation and systemic readiness. Translanguaging pedagogy ensures linguistic access and cognitive equity; policy and teacher identity shape the socio-professional foundation for change; and AI technologies provide the practical means to operationalise adaptive, student-centered learning. The interplay among these elements reveals that AI cannot function as a standalone solution, it must operate within a supportive ecosystem that values human agency, cultural diversity and reflective practice. The reviewed literature further suggests that AI-driven EMI mathematics classrooms represent an evolving hybrid space where linguistic negotiation, digital mediation and disciplinary learning intersect. This hybridisation aligns with global educational shifts toward personalised learning, competence-based assessment and intercultural communication.

Nevertheless, several limitations constrain current research trajectories. First, most empirical studies adopt short-term designs or focus on specific technologies rather than longitudinally evaluating sustained learning outcomes. Second, few studies provide cross-cultural comparisons that might reveal how contextual variables such as national language policy or technological infrastructure shape AI adoption in EMI classrooms. Third, ethical considerations including data privacy, algorithmic transparency and linguistic bias remain underexplored in mathematics-focused AI research. Addressing these gaps requires multidisciplinary research that integrates educational technology, applied linguistics, and mathematics education to develop contextually grounded and ethically responsible frameworks. Future research should explore how AI systems can simultaneously track linguistic and mathematical progress, adapt feedback based on learner profiles and support teachers in interpreting multimodal data for formative assessment.

In practical terms, the findings of this review hold significant implications for educators, policymakers and curriculum designers. Educational institutions should promote teacher professional development programs emphasising AI literacy and translanguaging pedagogy to enhance classroom inclusivity. Policymakers should prioritise infrastructure investments that ensure equitable access to AI tools and digital platforms, particularly in multilingual contexts. Furthermore, curriculum developers should integrate AI-supported scaffolding mechanisms into EMI mathematics instruction, enabling personalised and linguistically responsive learning pathways. By doing so, education systems can better align technological innovation with linguistic diversity and cognitive development. Ultimately, the synthesis underscores that AI integration in English-medium mathematics instruction is not merely a technological transformation but a socio-pedagogical evolution that demands collaboration, reflexivity and sustained inquiry

VII. CONCLUSION

This systematic review set out to examine how technological innovations and AI are reshaping English-medium mathematics instruction for non-native speakers. The study aimed to synthesise emerging evidence from 22 peer-reviewed articles identified through Scopus and Web of Science using the PRISMA framework. The analysis revealed three dominant thematic domains. Collectively, these themes illustrate the growing convergence of linguistic inclusivity, technological adaptation and pedagogical innovation within multilingual educational environments. The results underscore that while AI technologies hold strong potential for enhancing mathematical understanding and language mediation, their successful implementation depends heavily on teacher preparedness, institutional policy support and equitable access to digital infrastructure. AI-driven tools, when effectively aligned with translanguaging strategies and contextual pedagogy, can transform English-medium mathematics classrooms into dynamic spaces of interaction and inclusivity, fostering both linguistic competence and cognitive development among learners.

The study contributes to the advancement of knowledge in the intersection of mathematics education, educational technology and English-medium instruction by highlighting both progress and persisting challenges. Evidence from the reviewed studies indicates that AI-mediated instruction facilitates adaptive learning and multimodal engagement, yet challenges such as digital inequality, limited teacher training and insufficient policy coherence continue to impede large-scale transformation. The review also emphasises the importance of balancing technological innovation with pedagogical integrity and ethical responsibility, ensuring that AI applications serve as instruments for empowerment rather than exclusion. Future research should adopt longitudinal and cross-cultural approaches to evaluate the sustained cognitive and linguistic impact of AI integration, explore ethical

frameworks to mitigate algorithmic bias and develop collaborative teacher education models that embed technological fluency and intercultural competence. Ultimately, the synthesis highlights that the integration of AI in English-medium mathematics instruction represents more than a digital shift. It signifies a broader pedagogical reorientation toward inclusivity, interdisciplinarity and evidence-based innovation capable of preparing learners for an increasingly interconnected and technologically driven world.

ACKNOWLEDGEMENT

Thank you to everyone involved in the publication of this article.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abdel Latif, M. M. M., & Alrashed, M. (2025). Teachers' Perspectives on English Medium Instruction (EMI) in Saudi University STEM Programmes. *International Journal of Engineering Education*, *41*(1), 136–147. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85216853727&partnerID=40&md5=a85c350fe5dddf322eb5417eaa03b0fc

Abouzahra, A., Sabraoui, A., & Afdel, K. (2020). Model composition in Model Driven Engineering: A systematic literature review. *Information and Software Technology*, *125*(May), 106316. https://doi.org/10.1016/j.infsof.2020.106316

Bashyam, S., Colomer, M., Santhanagopalan, R., Kinzler, K. D., & Woodward, A. (2023). Children's Language-Based Pedagogical Preferences in a Multilingual Society. *Journal of Experimental Psychology: General*, *153*(12), 2951–2961. https://doi.org/10.1037/xge0001497

Block, D. (2021). Emergent STEM lecturer identities: The shaping effects of EMI in action in an internationalised and Englishised HE context. *Language Teaching*, *54*(3), 388–406. https://doi.org/10.1017/S0261444820000221

Block, D., & Moncada-Comas, B. (2022). English-medium instruction in higher education and the ELT gaze: STEM lecturers' self-positioning as NOT English language teachers. *International Journal of Bilingual Education and Bilingualism*, *25*(2), 401–417. https://doi.org/10.1080/13670050.2019.1689917

Bonney, E. N., Campbell, A., Adesina, K. A., Okaijah, M., & Prempeh, F. A. (2025). "I knew I had Issues with my Maths, but I Never Thought it could be Because of the Language": Student Success in Mathematics Using Home Languages and Educational Technology. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-025-10575-6

Cooper, N., Clark, A. T., Lecomte, N., Qiao, H., & Ellison, A. M. (2024). Harnessing large language models for coding, teaching and inclusion to empower research in ecology and evolution. *Methods in Ecology and Evolution*, *15*(10), 1757–1763. https://doi.org/10.1111/2041-210X.14325

Dai, L., & Wu, F. (2025). An AI-powered conversational system for college students learning English as a second language. *Education and Information Technologies*. https://doi.org/10.1007/s10639-025-13640-3

De Costa, P. I., Hartman, D., Green-Eneix, C., & Montgomery, D. P. (2025). Advancing CLIL Approaches in EMI Settings Through International Collaboration: An Introduction. *Chinese Journal of Applied Linguistics*, *48*(1), 3–11. https://doi.org/10.1515/CJAL-2025-0101 WE - Emerging Sources Citation Index (ESCI)

Dmitrenko, N., Koliadych, Y., Melnyk, L., & Voloshina, O. (2024). The use of ICT in learning ESP by pre-service teachers of Mathematics in the wartime. *Texto Livre*, *17*. https://doi.org/10.1590/1983-3652.2024.47588

Eyal, E., & Hayak, M. (2025). The integration of digital games into teaching and learning—A unique constructivist framework. *British Journal of Educational Technology*, *56*(5), 2202–2222. https://doi.org/10.1111/bjet.13555

Gonzalez-Nucamendi, A., Noguez Monroy, J., Neri, L., Robledo-Rella, V., & Garcia-Castelan, R. M. G. (2023). Predictive analytics study to determine undergraduate students at risk of dropout. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1244686

Gu, M. M., Ou, A. W., & Lee, C. K. J. (2025). Translanguaging and transknowledging practices among STEM teachers in EMI higher education. *Applied Linguistics Review*. https://doi.org/10.1515/applirev-2025-0155

Guo, Q. (2023). Minimizing Emotional Labor through Artificial Intelligence for Effective Labor Management of English Teachers. *Journal of Combinatorial Mathematics and Combinatorial Computing*, *117*, 37–46. https://doi.org/10.61091/jcmcc117-04

Huang, W., & Fang, F. (2023). EMI Teachers' perceptions and practices regarding culture teaching in Chinese higher education. *Language, Culture and Curriculum*, *36*(2), 205–221. https://doi.org/10.1080/07908318.2022.2115056

Hürsen, C., Paşa, D., & Keser, H. (2023). High School Students' Use of Information, Media, and Technology Skills and Multidimensional 21st-Century Skills: An Investigation within the Context of Students, Teachers, and Curricula. *Sustainability (Switzerland)*, *15*(16). https://doi.org/10.3390/su151612214

Jeong, S.-J., & Kim, B.-M. (2021). Network analysis of social awareness of media education for primary school students studied through big data. *Computer*

Science and Information Systems, *18*(2), 575–595. https://doi.org/10.2298/CSIS200316011J

Jing, C., Zhao, X., Ren, H., Chen, X., & Gaowa, N. (2022). An Approach to Oral English Assessment Based on Intelligent Computing Model. *Scientific Programming*, *2022*. https://doi.org/10.1155/2022/4663574

Leung, C.-H. D., Chow, M.-Y. V., & Ge, H. (2024). Compiling data for investigating language use in classroom discourse: A corpus-driven method. *MethodsX*, *13*. https://doi.org/10.1016/j.mex.2024.103048

Li, M. (2025). Integrating Artificial Intelligence in Primary Mathematics Education: Investigating Internal and External Influences on Teacher Adoption. *International Journal of Science and Mathematics Education*, *23*(5), 1283–1308. https://doi.org/10.1007/s10763-024-10515-w

Li, X., Zappatore, M., Li, T., Zhang, W., Tao, S., Wei, X., Zhou, X., Guan, N., & Chan, A. (2025). GAI Versus Teacher Scoring: Which is Better for Assessing Student Performance? *IEEE Transactions on Learning Technologies*, *18*, 569–580. https://doi.org/10.1109/TLT.2025.3572518

Lockwood, C., Munn, Z., & Porritt, K. (2015). Qualitative research synthesis: Methodological guidance for systematic reviewers utilizing meta-aggregation. *International Journal of Evidence-Based Healthcare*, *13*(3), 179–187. https://doi.org/10.1097/XEB.0000000000000062

Manan, S. A., & Hajar, A. (2024). Understanding English medium instruction (EMI) policy from the perspectives of STEM content teachers in Kazakhstan. *TESOL Journal*, *15*(4). https://doi.org/10.1002/tesj.847

Manan, S. A., Kairatova, S., Mukhamediyeva, S., Tajik, M. A., & Hajar, A. (2025). From policy dumping to a participatory framework: re-envisioning the English medium instruction policy in Kazakhstan's mainstream schools. *Asian Englishes*, *27*(1), 60–74. https://doi.org/10.1080/13488678.2024.2343512

Montgomery, D., de Costa, P. I., & Novitskaya, Y. (2025). Forging CLIL Teacher Identities in Kazakhstan: Developmental Pathways of Two University Teachers. *Chinese Journal of Applied Linguistics*, *48*(1), 30–49. https://doi.org/10.1515/CJAL-2025-0103

Mudau, A. V, & Sikhosana, L. (2025). The influence of the fourth industrial revolution in teaching and learning: the COVID-19 context. *F1000Research*, *12*. https://doi.org/10.12688/f1000research.131618.3

Page, M. J., McKenzie, J. E., Bossuyt, P., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The prisma 2020 statement: An updated guideline for reporting systematic reviews. *Medicina Fluminensis*, *57*(4), 444–465. https://doi.org/10.21860/medflum2021_264903

Prates, M. O. R., da Costa Avelar, P. H., & Lamb, L. C. (2020). Assessing gender bias in machine translation: a case study with Google Translate. *Neural Computing and Applications*, *32*(10), 6363–6381. https://doi.org/10.1007/s00521-019-04144-6

Rahman, M. M., & Manjet, M. K. M. (2022). English Medium university STEM teachers' and students' ideologies in constructing content knowledge through translanguaging. *International Journal of Bilingual Education and Bilingualism*, *25*(7), 2435–2453. https://doi.org/10.1080/13670050.2021.1915950

Robertson, S.-A., & Graven, M. (2020). Language as an including or excluding factor in mathematics teaching and learning. *Mathematics Education Research Journal*, *32*(1), 77–101. https://doi.org/10.1007/s13394-019-00302-0

Sun, N. (2023). English Speaking Teaching Strategies Based on Natural Language Processing. *Journal of Electrical Systems*, *19*(4), 102–115. https://doi.org/10.52783/jes.626

Sun, Z., Anbarasan, M., & Praveenkumar, D. (2021). Design of online intelligent English teaching platform based on artificial intelligence techniques. *Computational Intelligence*, *37*(3), 1166–1180. https://doi.org/10.1111/coin.12351

Tai, K. W. H. (2023). Creating translanguaging spaces in a Hong Kong English medium instruction mathematics classroom: A comparative analysis of classroom interactions with and without the use of iPad. *Linguistics and Education*, *78*. https://doi.org/10.1016/j.linged.2023.101227

Tai, K. W. H. (2024). Classroom interactional competence in an English medium instruction mathematics classroom: A creation of a technology-mediated translanguaging space. *Learning and Instruction*, *90*. https://doi.org/10.1016/j.learninstruc.2023.101849

Tai, K. W. H., & Wei, L. (2024). The affordances of iPad for constructing a technology-mediated space in Hong Kong English medium instruction secondary classrooms: A translanguaging view. *Language Teaching Research*, *28*(4), 1501–1551. https://doi.org/10.1177/13621688211027851

Taifour, E. A., & Alabdulaziz, M. S. (2025). Language Challenges in Mathematics Courses for Non-Native English-speaking Students: A Literature Review. *International Journal of Learning, Teaching and Educational Research*, *24*(3), 740–757. https://doi.org/10.26803/ijlter.24.3.35

Uğraş, H., Uğraş, M., Papadakis, S., & Kalogiannakis, M. (2024). ChatGPT-Supported Education in Primary Schools: The Potential of ChatGPT for Sustainable Practices. *Sustainability (Switzerland)*, *16*(22). https://doi.org/10.3390/su16229855

Wang, W. (2022). College English Teaching Platform Optimization under Cross-Media and Mobile Internet Environment. *Computational Intelligence and Neuroscience*, *2022*. https://doi.org/10.1155/2022/9672463

Zakaria, R., Herwanis, D., Wahyuni, S., Abadi, A., Umar, A., & Mandasari, L. (2024). AI in English and Math Education: Bridging the Gap Between Theory and Practice. *Communications on Applied Nonlinear Analysis*, *31*(6S), 1–13. https://doi.org/10.52783/cana.v31.1101

Zapata-Rivera, D., VanWinkle, W., Doyle, B., Buteux, A., & Bauer, M. (2009). Combining learning and assessment in assessment-based gaming environments: A case study from a New York City school. *Interactive Technology and Smart Education*, *6*(3), 173–188. https://doi.org/10.1108/17415650911005384

Zhou, C. (2023). Integration of modern technologies in higher education on the example of artificial intelligence use. *Education and Information Technologies*, *28*(4), 3893–3910. https://doi.org/10.1007/s10639-022-11309-9