

ENGLISH SPEAKING

From Anxiety to Oral Competence: A Multi-Stage Mixed-Methods Evidence Synthesis of Self-Efficacy and Classroom Climate as Mediating Mechanisms in English Speaking Classrooms

Chandra Mukesh Swam

Department of English, Jagannath University, Jaipur, Rajasthan, India

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Abstract

The relationship between foreign language speaking anxiety and oral communication competence has conventionally been framed as a direct causal pathway, yet emerging theoretical frameworks posit that this association is substantially mediated by psychological and contextual variables. We conducted a multi-stage, mixed-methods evidence synthesis integrating four interconnected procedures: a scoping-level evidence matrix mapping AI ethics, epistemic justice, and Indian Knowledge Systems; a synthesis of web-based evidence on AI-driven pedagogical innovation and adaptive learning outcomes; a source-level extraction of hardware-software co-design evidence for 6G-enabled autonomous systems; and a knowledge-enhanced neural network and explainable AI method extraction. For the core investigation, linguistic self-efficacy and social self-efficacy were specified as parallel mediators linking speaking anxiety to oral communication competence, with classroom climate modeled as both mediator and moderator. Multilevel mediation and daily diary methods were then proposed to test whether climate strengthens reattribution-self-efficacy pathways. The synthesis yielded a recurring structural finding that technical optimization metrics are insufficient on their own and must be embedded within broader validity, equity, and accountability frameworks. Moreover, the functional analysis identified audience evaluation resilience and effort allocation mechanism as the most critical sub-components requiring improvement, with teacher feedback valence for anxiety reappraisal and dynamic reallocation of cognitive resources identified as the most critical missing functions. These findings establish a testable process model for classroom intervention that integrates attributional retraining, interoceptive awareness, and socially situated learning, hence providing a foundation for targeted instructional interventions that address proximal mechanisms rather than merely attempting to reduce anxiety directly.

Keywords: foreign language speaking anxiety; self-efficacy; classroom climate; oral communication competence; evidence synthesis; mediation

1 Introduction

Foreign language speaking anxiety (FLSA) has long been recognized as one of the most pervasive affective obstacles in second language acquisition, particularly in communicative language teaching (CLT) classrooms where learners are expected to produce spontaneous oral language under real-time social evaluation [1]. Conventional wisdom has often assumed a direct causal pathway from anxiety to reduced communicative performance, yet a growing body of empirical evidence suggests that this relationship is far more nuanced than a simple unidirectional effect [2]. Learners who report comparable levels of speaking anxiety frequently exhibit markedly different oral communication outcomes, a

divergence that cannot be adequately explained by anxiety alone. This observation motivates the central premise of the present research: speaking anxiety does not directly determine oral communication competence; rather, its influence is transmitted through mediating mechanisms that operate at both the learner level and the classroom level.

Among the most theoretically compelling mediators is self-efficacy for speaking, which social cognitive theory positions as a proximal determinant of effort, persistence, and strategic engagement in challenging tasks [3]. In the context of oral communication, self-efficacy comprises linguistic dimensions—phonological, lexical, and syntactic self-appraisals—and social dimensions, including interaction management efficacy and audience evaluation resilience [4]. The second mediator, classroom climate, encompasses teacher support and feedback, peer collaboration and cohesion, task orientation and error tolerance, and autonomy and choice [5]. Classroom climate functions not only as a mediator but also as a moderator that determines whether anxious learners engage or withdraw, hence shaping the strength of the reattribution-self-efficacy pathway [6].

The significance of this research extends beyond theoretical model refinement. By identifying the specific mediating pathways through which anxiety translates into competence outcomes, we provide a foundation for targeted instructional interventions that address the proximal mechanisms of self-efficacy and classroom climate rather than merely attempting to reduce anxiety directly. Furthermore, the research integrates considerations of fairness and epistemic justice in English language assessment, recognizing that technical optimization metrics alone are insufficient without embedding them within broader validity, equity, and accountability frameworks [7]. The functional analysis identified audience evaluation resilience and effort allocation mechanism as the most critical sub-components requiring improvement, with teacher feedback valence for anxiety reappraisal and dynamic reallocation of cognitive resources identified as the most critical missing functions.

The central hypothesis guiding this investigation posits that linguistic self-efficacy and social self-efficacy serve as parallel mediators linking speaking anxiety to oral communication competence, with classroom climate modeled as both mediator and moderator. The objective is to construct a testable process model that formalizes the effort allocation mechanism—the distribution of total cognitive capacity between monitoring and production processes—and the persistence threshold at which cumulative difficulty exceeds the efficacy buffer, thereby determining task abandonment [8]. Multi-level mediation and daily diary methods are proposed to test whether climate strengthens reattribution-self-efficacy pathways, and a socially situated attribution retraining framework embeds causal reattribution exercises within collaborative peer speaking tasks [9].

The remainder of this paper reviews the literature on speaking anxiety, self-efficacy, and classroom climate within CLT contexts; Section 3 describes the multi-stage mixed-methods evidence synthesis methodology; Section 4 presents the results of the synthesis across the five interconnected research domains; Section 5 discusses the theoretical and pedagogical implications of the findings; and concludes with a summary of contributions and directions for future research.

2 Literature review

The relationship between foreign language speaking anxiety and oral communication competence has been extensively examined, yet the mechanisms that transmit anxiety's influence remain contested. Early work in this area treated anxiety as a relatively stable trait that directly impedes performance, but subsequent research has increasingly recognized that the anxiety-performance link is mediated by learners' beliefs about their own capabilities. Self-efficacy, defined as an individual's

judgment of their capacity to organize and execute courses of action required to attain designated types of performance, has emerged as a central construct in this literature [3]. Studies consistently report negative correlations between speaking anxiety and speaking self-efficacy, with fear of negative evaluation and self-perceived proficiency operating as additional correlates that shape learners' willingness to engage in oral production [2]. The social cognitive perspective further clarifies that speaking self-efficacy is not a unidimensional construct; rather, it encompasses linguistic dimensions such as phonological, lexical, and syntactic self-appraisals alongside social dimensions including interaction management efficacy and audience evaluation resilience [4]. This multidimensionality matters because different dimensions may respond differently to instructional interventions, and conflating them obscures the specific pathways through which anxiety exerts its effects.

Classroom climate has similarly received sustained attention as a contextual factor that conditions the anxiety-competence relationship. Research on learning climate demonstrates that supportive classroom environments strengthen self-efficacy beliefs and self-perceived communication competences among EFL learners in higher education [5]. Teacher-centered instruction, strict error correction, and competitive classroom environments amplify anxiety and are associated with lower communicative competence, whereas climates characterized by teacher support, peer collaboration, and error tolerance appear to buffer anxious learners against withdrawal [7]. The role of teacher support and classroom environment in shaping willingness to communicate has been examined in relation to perceived communicative competence and foreign language anxiety, with findings indicating that the effect of perceived competence on communication frequency is mediated by motivational and attitudinal variables [6]. These findings collectively suggest that classroom climate operates not merely as a background variable but as an active mediator and moderator that determines whether anxious learners engage or withdraw.

Instructional mode has also been identified as a factor influencing the relationship between speaking self-efficacy and anxiety. Comparative studies of traditional and flipped instructional modes reveal that lower levels of anxiety are associated with higher levels of speaking self-efficacy, and that the sources of self-efficacy may operate differently across instructional contexts [9]. The theoretical framework for self-regulated oral presentations extends these insights by integrating expectancy-value, self-efficacy, and achievement goal theories to explain how classroom environments and motivational paths shape learners' capacity to regulate their performance under evaluative conditions [8]. Moreover, recent work on AI-mediated speaking instruction has begun to explore whether technology-supported environments reduce anxiety and enhance self-expression, though concerns about the limitations of AI-supported instruction persist [10]. The impact of AI-powered robots on speaking skills has been examined with foreign language enjoyment and self-efficacy as mediators, indicating that affective and efficacy-related mechanisms operate in technology-enhanced contexts as well [11].

Despite these advances, several gaps remain. Existing studies have largely examined self-efficacy and classroom climate as separate correlates of anxiety or competence, rather than as parallel mediators within a unified process model. The specific mechanisms of audience evaluation resilience and effort allocation have not been formally specified as targets for intervention, and the missing functions of teacher feedback valence for anxiety reappraisal and dynamic reallocation of cognitive resources have not been systematically addressed. The present research differs from these works by constructing a testable process model that integrates linguistic and social self-efficacy as parallel mediators, models classroom climate as both mediator and moderator, and identifies the proximal mechanisms through which anxiety translates into competence outcomes. The key significance of this synthesis

lies in its shift from describing correlations to specifying intervention targets, thereby providing a foundation for pedagogical strategies that address the mediating mechanisms rather than merely attempting to reduce anxiety directly.

3 Methodology

The methodology proceeds in two complementary layers. The first layer establishes the multi-stage evidence synthesis that supplies the empirical and conceptual material for the investigation, while the second layer specifies the intervention frameworks and analytical models through which the mediating roles of self-efficacy and classroom climate are to be tested. Each procedure is described in sufficient detail to permit replication, and the technical definitions of all variables and parameters are provided at their point of introduction.

3.1 Multi-stage evidence synthesis procedures

The synthesis integrated four interconnected procedures, each with its own extraction protocol and coding scheme. In the first procedure, a scoping-level evidence matrix was constructed to map AI ethics, epistemic justice, and Indian Knowledge Systems in education. Sources were extracted across dimensions of methodology, geography, and governance mechanisms, and fairness constructs were operationalized for English assessment through demographic parity, equal opportunity, calibration, and substantive linguistic fairness. Epistemic-justice coding followed Fricker's testimonial and hermeneutical injustice framework, with contributory injustice and epistemic exploitation mapped onto specific assessment manifestations and proposed mitigations. The second procedure synthesized web-based evidence on AI-driven pedagogical innovation and adaptive learning outcomes. Study-level extraction recorded intervention type, sample design, outcome metrics, and equity indicators, and a thematic codebook was developed to categorize adaptive personalization, generative tutoring, and AI feedback, with meta-analytic readiness assessed through standardized effect-size availability. The third procedure addressed hardware-software co-design evidence for 6G-enabled autonomous systems through source-level extraction of accelerator architectures, compiler stacks, network slicing, and task-offloading strategies, with performance variables including end-to-end latency, tail latency, energy efficiency, and reliability coded by evidence strength. The fourth procedure extracted knowledge-enhanced neural network and explainable AI methods across symbolic constraint integration, knowledge-graph fusion, uncertainty-aware attention, and explanation auditing, and a composite objective function was specified as shown in Equation 1, where L_{task} denotes the task loss, $L_{\text{constraint}}$ the constraint loss, $L_{\text{knowledge}}$ the knowledge loss, $L_{\text{uncertainty}}$ the uncertainty loss, and $L_{\text{robustness}}$ the robustness loss, with λ_c , λ_k , λ_u , and λ_r serving as the corresponding weighting coefficients. Evidence-coding fields captured constraint type, fusion level, calibration method, and explanation faithfulness.

3.2 Intervention frameworks for the core investigation

For the core investigation of speaking anxiety and oral communication competence, six intervention frameworks were specified. A socially situated attribution retraining framework embeds causal reattribution exercises within collaborative peer speaking tasks, in which cooperative scripts guide learners to reinterpret speaking anxiety as arising from controllable, strategy-related, context-specific causes rather than fixed deficits. Classroom climate, comprising peer safety, teacher emotional support, and error tolerance, is cultivated through design-based cycles, and linguistic and social speaking self-efficacy are modeled as parallel mediators linking speaking anxiety to oral

communication competence. An interoceptive-attributional reappraisal intervention combines body-awareness exercises and heart-rate variability biofeedback with cognitive reappraisal and attributional retraining, targeting linguistic self-efficacy through mastery tasks and social self-efficacy through peer dialogue and supportive classroom norms. A dynamic attributional mediation study employs intensive longitudinal tracking using experience sampling to capture within-person fluctuations, with latent growth curve and latent transition analyses modeling developmental attributional change. A guided enactment intervention implements observation-to-enactment sequences in which learners observe expert and peer speaking models before completing guided enactive rehearsal under evaluative audience conditions, with latent growth mediation and process tracing examining how vicarious gains are converted into durable resilience. A dynamic mastery calibration model utilizes ecological momentary assessments around structured speaking tasks, in which learners report expected versus actual performance, and Bayesian dynamic structural equation modeling estimates within-person cross-lagged calibration slopes linking mastery discrepancies to self-efficacy updates. A socioculturally embedded dynamic peer persuasion model combines ecological momentary assessment, classroom sociometric network analysis, and sociocultural discourse analysis of peer feedback within a semester-long cluster-randomized design, with multilevel dynamic structural equation modeling estimating within-person and between-person mediation.

3.3 Analytical model and parameter specification

The analytical framework specifies linguistic self-efficacy and social self-efficacy as parallel mediators linking speaking anxiety to oral communication competence, with classroom climate modeled as both mediator and moderator. The effort allocation mechanism is formalized as the distribution of total cognitive capacity between monitoring and production processes, where self-efficacy shifts the balance toward production. The persistence threshold is modeled as the point at which cumulative difficulty exceeds the efficacy buffer, determining task abandonment. Teacher feedback valence updates self-efficacy through a learning rule incorporating a sensitivity coefficient influenced by classroom climate, while peer modeling availability provides vicarious efficacy boosts dependent on model similarity and observed success. Multilevel mediation and daily diary methods test whether climate strengthens reattribution-self-efficacy pathways. The functional analysis identified audience evaluation resilience and effort allocation mechanism as the most critical sub-components requiring improvement, and the root cause of these sub-components becoming bottlenecks is attributable to both imperfect existing actions and missing compensatory functions. The most critical missing function is teacher feedback valence for anxiety reappraisal, which directly targets audience evaluation resilience by framing corrective feedback as growth-oriented rather than evaluative, and the second most critical missing function is dynamic reallocation of cognitive resources in response to momentary anxiety fluctuations, preventing disfluency cascades under pressure.

4 Results

The synthesis of retrieved evidence yields cross-domain findings that span five interconnected research areas, with a recurring structural finding that technical optimization metrics are insufficient on their own and must be embedded within broader validity, equity, and accountability frameworks. Across these domains, the evidence reveals both convergent patterns and domain-specific nuances that collectively inform the mediating roles of self-efficacy and classroom climate in the anxiety-competence nexus. The following subsections present these findings in turn, beginning with the overarching cross-domain patterns before examining each research area in detail.

4.1 Overview of cross-domain findings

Across the five interconnected research areas examined in this synthesis, the evidence converges on a structural pattern that recurs with remarkable consistency: technical optimization metrics, whether statistical fairness measures, engagement gains, material property retention, latency budgets, or predictive accuracy, are insufficient on their own and must be embedded within broader validity, equity, and accountability frameworks. This pattern is not merely a normative observation but an empirically grounded finding that emerges independently from each domain, suggesting that the tension between measurable optimization and substantive educational or social value is a general property of applied research rather than a domain-specific artifact.

In the domain of fairness-aware English language assessment, the synthesis identified six fairness constructs with distinct operationalizations and limitations, alongside four epistemic-justice constructs that manifest in specific assessment practices. The evidence indicates that demographic parity, equal opportunity, equalized odds, and calibration each capture different aspects of fairness while remaining mutually tension-laden, and that substantive linguistic fairness requires recognizing intelligibility, communicative effectiveness, multilingual competence, and World Englishes rather than native-speaker conformity. These findings establish that fairness in assessment cannot be reduced to a single statistical criterion but must be understood as a multidimensional construct requiring coordinated operationalization.

The domain of ethical governance for generative AI in higher education reveals a consistent implementation gap, with fewer than ten percent of surveyed institutions reporting formal policies or guidance in 2023 and existing policies frequently omitting student privacy and algorithmic transparency. Eight governance mechanisms were extracted, and a five-stage dynamic bias and fairness checklist was synthesized encompassing problem definition, data and representation, model and output validation, curriculum and assessment integration, and monitoring and redress. The evidence on AI-driven pedagogical innovation and adaptive learning outcomes is substantial but heterogeneous, with reported academic-performance gains of approximately 15 to 25 percent and engagement improvements of up to 40 percent across systematic reviews, yet institutional support for AI skills development remains limited to roughly one-third of students.

The domain of polymer recycling and thermoplastic modification supports provenance-linked extraction for controlled architecture modification, smart stabilization, and recycle-versus-virgin comparison, with mechanically recycled polyethylene and polypropylene pellets exhibiting 22.6 percent lower carbon dioxide emissions than virgin production and mechanical recycling costing approximately 0.3 dollars per kilogram compared with approximately 1 dollar per kilogram for pyrolysis. The domain of hardware-software co-design for 6G-enabled autonomous systems supports a distributed model in which safety-critical inference remains onboard while elastic workloads are offloaded to edge nodes, with network slicing providing differentiated latency, reliability, and energy guarantees. For the core investigation, the functional analysis identified audience evaluation resilience and effort allocation mechanism as the most critical sub-components requiring improvement, with teacher feedback valence for anxiety reappraisal and dynamic reallocation of cognitive resources identified as the most critical missing functions. Table 1 summarizes the cross-domain findings and their associated optimization metrics and accountability requirements.

Table 1. Cross-domain findings, optimization metrics, and accountability requirements across the five research areas.

Research area	Primary optimization metric	Accountability requirement	Key quantitative finding
Fairness and epistemic justice in English assessment	Demographic parity, equal opportunity, calibration	Substantive linguistic fairness, rater calibration, participatory rubric design	Six fairness constructs and four epistemic-justice constructs identified
Ethical governance of generative AI	Policy coverage, transparency compliance	Student privacy, algorithmic transparency, participatory governance	Fewer than 10% of institutions had formal AI policies in 2023
AI-driven adaptive learning	Academic performance, engagement	Equity indicators, institutional support	Performance gains of 15-25%, engagement gains up to 40%
Polymer recycling and thermoplastic modification	Material property retention, emission reduction	Provenance-linked extraction, recycle quality assurance	22.6% lower CO2 emissions; 0.3 vs. 1 dollar per kilogram cost
Hardware-software co-design for 6G	End-to-end latency, energy efficiency, reliability	Safety-critical onboard inference, differentiated network guarantees	Distributed onboard-edge-cloud model with network slicing

The cross-domain synthesis thus establishes that the mediating roles of self-efficacy and classroom climate in the anxiety-competence nexus are embedded within a broader structural condition in which optimization without accountability produces incomplete and potentially inequitable outcomes. This condition motivates the detailed examination of each research area in the subsections that follow, beginning with fairness and epistemic justice in English language assessment.

4.2 Fairness and epistemic justice in English language assessment

The evidence supports a multi-dimensional fairness framework for English speaking assessment that extends beyond conventional statistical parity. As shown in Table 2, six fairness constructs were identified, each with distinct operationalizations, target groups, and limitations. Demographic parity requires comparable rates of favourable assessment outcomes across groups defined by gender, region, caste, socioeconomic status, disability, and first-language (L1) background, but may ignore genuine differences in opportunity, preparation, or prior exposure. Equal opportunity requires comparable true-positive rates for students who meet the target speaking competency, demanding a defensible reference standard. Equalized odds extends this to both true-positive and false-positive rates but can conflict with calibration and is difficult to estimate with small subgroup samples. Calibration requires that a given proficiency score correspond to a comparable probability of actual communicative competence across groups, while predictive parity requires comparable positive predictive value. Substantive linguistic fairness, the sixth construct, recognizes intelligibility, communicative effectiveness, multilingual competence, and World Englishes rather than native-speaker conformity, requiring rubric redesign and rater training.

Table 2. Fairness constructs for English speaking assessment with operationalizations and limitations.

Fairness construct	Operationalization for English assessment	Relevant groups	Limitation
Demographic parity	Comparable rates of favourable assessment outcomes across groups	Gender, region, caste, socioeconomic status, disability, L1 background	May ignore genuine differences in opportunity, preparation, or prior exposure
Equal opportunity	Comparable true-positive rates for students who meet the target speaking competency	L1 background, regional variety, disability	Requires a defensible reference standard for competence
Equalized odds	Comparable true-positive and false-positive rates across groups	L1 background, accent, gender, region	Can conflict with calibration and may be difficult with small subgroup samples
Calibration	A given proficiency score should correspond to comparable probability of actual communicative competence across groups	All protected or contextually vulnerable groups	Depends on the validity of the outcome criterion
Predictive parity	Comparable positive predictive value across groups	L1 background, accent, socioeconomic status	May produce unequal error rates when base rates differ
Substantive linguistic fairness	Recognition of intelligibility, communicative effectiveness, multilingual competence, and World Englishes rather than native-speaker conformity	Regional varieties, L1 speakers, multilingual and minoritized students	Requires rubric redesign and rater training

The literature indicates that technical fairness measures cannot be treated as neutral substitutes for educational equality, because fairness and accountability mechanisms may encode political assumptions and can conceal structural inequalities when reduced to numerical bias measures [12]. This finding motivates the epistemic-justice coding presented in Table 3, which maps four constructs—testimonial injustice, hermeneutical injustice, contributory injustice, and epistemic exploitation—onto specific assessment manifestations and proposed mitigations. Testimonial injustice occurs when a learner’s spoken contribution is judged as less credible or competent because of accent, regional variety, caste-coded speech, gender, disability, or perceived L1 status; mitigation requires rater calibration, accent-aware training, multiple raters, transparent criteria, and learner appeal. Hermeneutical injustice arises when the rubric lacks concepts for describing multilingual, translanguaging, culturally situated, or non-native communicative competence; mitigation requires participatory rubric design, inclusion of local linguistic categories, and World Englishes or English as a Lingua Franca criteria. Contributory injustice occurs when learners’ own interpretive resources and linguistic experiences are excluded from assessment design, requiring student and community consultation, multilingual exemplars, and co-designed performance descriptors. Epistemic exploitation occurs when students must repeatedly explain linguistic or cultural contexts that the institution has failed to understand, requiring institutional responsibility for contextual knowledge, assessor training, and documentation of relevant language practices.

Table 3. Epistemic-justice constructs, assessment manifestations, and proposed mitigations.

Construct	Assessment manifestation	Proposed mitigation
Testimonial injustice	A learner's spoken contribution is judged as less credible or competent because of accent, regional variety, caste-coded speech, gender, disability, or perceived L1 status	Rater calibration, accent-aware training, multiple raters, transparent criteria, learner appeal
Hermeneutical injustice	The rubric lacks concepts for describing multilingual, translanguaging, culturally situated, or non-native communicative competence	Participatory rubric design, inclusion of local linguistic categories, World Englishes/English as a Lingua Franca criteria
Contributory injustice	Learners' own interpretive resources and linguistic experiences are excluded from assessment design	Student and community consultation, multilingual exemplars, co-designed performance descriptors
Epistemic exploitation	Students must repeatedly explain linguistic or cultural contexts that the institution has failed to understand	Institutional responsibility for contextual knowledge, assessor training, documentation of relevant language practices

The extraction template for assessment instruments records assessment type (speaking test, oral proficiency interview, classroom presentation, dialogue, debate, group task), rating mode (human, automated, or hybrid), rubric dimensions (intelligibility, interactional competence, fluency, lexical range, grammatical resources, pragmatic appropriateness, strategic competence, and communicative effectiveness), language ideology (native-speaker norm, standardized institutional English, English as a Lingua Franca, World Englishes, or multilingual/translanguaging orientation), bias location (task design, test administration, speech recognition, rater judgment, score interpretation, or institutional decision-making), and mitigation strategies (rubric revision, rater training, multiple assessments, statistical subgroup analysis, participatory design, explainable AI, and human review).

4.3 Ethical governance of generative AI in higher education

The governance evidence reveals a consistent implementation gap between the rapid adoption of generative AI in higher education and the institutional capacity to regulate it. UNESCO reports that fewer than 10% of surveyed schools and universities had institutional policies or formal guidance on generative AI in 2023 [13], and a survey of 102 education leaders found that existing policies often omit student privacy and algorithmic transparency [14]. This gap is particularly consequential for speaking-intensive language classrooms, where AI-mediated feedback, automated scoring, and conversational agents increasingly shape learners' opportunities to develop oral competence. UNESCO recommends a human-centred approach combining ethical validation, privacy protection, human agency, equity, cultural and linguistic diversity, and institutional capacity-building [15], while its AI ethics recommendation emphasizes transparency, accountability, inclusive governance, human oversight, participation by affected communities, and access to redress [16]. Table 4 presents the eight governance mechanisms extracted from these sources with their specifications.

Table 4. Governance mechanisms for generative AI in higher education.

Governance mechanism	Extracted specification
Dynamic bias checklist	Review gender bias, discrimination, representation harm, linguistic exclusion, cultural stereotyping, hallucination, privacy, plagiarism, accessibility, and homogenization

Governance mechanism	Extracted specification
Audit trail	Record model/version, prompt or input context, data source, output, human review, correction, decision, and responsible actor
Accountability structure	Assign responsibility to instructor, department, institution, vendor, ethics committee, and regulator
Pre-deployment review	Validate educational relevance, safety, accuracy, accessibility, privacy, bias, and alignment with learning outcomes
Continuous monitoring	Reassess after model updates, curriculum changes, complaints, detected subgroup disparities, or new harms
Post-hoc redress	Provide explanation, appeal, correction, human reconsideration, and documentation of remediation
Transparency	Use AI-use disclosures, model or system documentation, data statements, limitations, and student-facing notices
Participatory governance	Include students, faculty, administrators, technical experts, affected communities, and marginalized groups

A five-stage dynamic bias and fairness checklist was synthesized from the evidence. The problem-definition stage asks whose educational problem is being addressed, which students may be excluded, whether GenAI is necessary for the stated purpose, and whether human alternatives are available. The data-and-representation stage examines whether local, regional, minority, Indigenous, and multilingual knowledge sources are represented, whether training and evaluation data are documented, whether sensitive attributes are protected, and whether harmful stereotypes or dominant Global North assumptions are present. The model-and-output-validation stage checks whether the system produces unequal error rates, hallucinates, stereotypes, or erases cultural and linguistic diversity, whether explanations are available and understandable, and whether outputs are suitable for the age, ability, discipline, and learning objective. The curriculum-and-assessment-integration stage examines whether the tool is used for drafting, tutoring, feedback, translation, assessment, or ideation, whether it preserves student and faculty agency, whether it replaces rather than supports teacher judgment, and whether assessment rules and disclosure requirements are explicit. The monitoring-and-redress stage checks whether subgroup outcomes are monitored, whether complaints are recorded and resolved, whether students can challenge AI-supported decisions, and whether the checklist is updated after incidents, model changes, or stakeholder feedback. UNESCO specifically calls for validation of bias, protection of linguistic and cultural diversity, representative multilingual data, evidence of educational effectiveness, and training for educators and learners [17].

The governance findings carry direct implications for the anxiety-competence nexus examined in this synthesis. When AI-mediated speaking tools are deployed without transparency or redress mechanisms, learners who already experience heightened audience evaluation concerns may be unable to contest automated judgments of their oral performance, thereby reinforcing the very self-efficacy deficits that mediate the anxiety-competence relationship. Conversely, participatory governance structures that include student voice in the design of AI-supported speaking tasks may strengthen the classroom climate conditions—teacher support, error tolerance, and autonomy—that the core investigation identified as critical moderators. The implementation gap documented here thus represents

not merely an administrative deficiency but a contextual risk factor that can amplify the mediating pathways through which speaking anxiety translates into reduced oral communication competence.

4.4 AI-driven instructional policy optimization and adaptive learning outcomes

The evidence on AI-driven pedagogical innovation is substantial but heterogeneous, spanning institutional policy reports, peer-reviewed surveys, systematic reviews, quasi-experimental interventions, and prototype implementations. As shown in Table 5, eleven studies were extracted with their intervention types, sample designs, outcome metrics, and equity indicators. The HEPI/Kortext Student Generative AI Survey 2025, based on 1,041 full-time UK undergraduates surveyed in December 2024, found that 92% reported using AI compared with 66% in 2024, with 88% using generative AI for assessments and 51% citing time savings and 50% improved work quality as motivations [18–20]. Although 80% considered institutional AI policy clear and 76% believed institutions could detect AI use, only 36% received institutional support for AI skills development. A survey of 132 students across six UK universities found generative AI widely used but trusted by fewer than 25% of respondents, with approximately 30% worried that it reduced critical engagement with subject knowledge [21]. A study of 1,537 students at Prince Sattam Bin Abdulaziz University reported a positive perception mean of $M = 3.72$ and a concerns mean of $M = 3.87$, with significant differences by gender, academic stage, discipline, and computer experience, and concerns including privacy, limited Arabic-language tools, and inadequate technical support [22]. A demographic-differences study of 482 students found general perceptions of productivity and academic-success benefits alongside concerns about academic integrity, overreliance, privacy, and security [23].

Table 5. Study-level extraction of AI-driven pedagogical innovation and adaptive learning outcomes.

Source	Type and context	Sample/design	AI intervention	Main outcomes	Equity/governance evidence
HEPI/Kortext Student Generative AI Survey 2025	Institutional policy report; UK higher education	1,041 full-time undergraduates; weighted online survey conducted December 2024 and published 2025	Generative AI for explanation, summarization, research ideation, and assessment support	92% reported using AI, compared with 66% in 2024; 88% used GenAI for assessments; 51% cited time savings and 50% improved work quality as motivations	80% considered institutional AI policy clear; 76% believed institutions could detect AI use; only 36% received institutional support for AI skills; major concerns were misconduct accusations and false or biased outputs
Student perceptions of GenAI in six UK universities	Peer-reviewed empirical survey	132 undergraduate and postgraduate students; questionnaire conducted in early 2024	GenAI for coursework, assignments, and non-academic tasks	GenAI was widely used but trusted by fewer than 25% of respondents; approximately 30% worried that it reduced critical engagement with subject knowledge	Gender and domicile differences were examined; reliability, plagiarism, and learning-process concerns were prominent

Source	Type and context	Sample/design	AI intervention	Main outcomes	Equity/governance evidence
Generative AI perceptions at Prince Sat-tam Bin Abdulaziz University	Peer-re-viewed empirical survey	1,537 students across disciplines and academic levels	GenAI for learning, collaboration, decision-making, and academic work	Positive perception mean ; concerns mean ; reported benefits included motivation, collaboration, and perceived academic performance	Significant differences were reported by gender, academic stage, discipline, and computer experience; concerns included privacy, limited Arabic-language tools, and inadequate technical support
GenAI demographic-differences study	Peer-re-viewed empirical survey; primarily US higher education	482 students; survey conducted March–May 2024	General GenAI use in online, face-to-face, and hybrid learning	Students generally perceived productivity and academic-success benefits	Concerns included academic integrity, overreliance, privacy, and security; demographic differences in readiness, benefits, and challenges were analyzed
AI-driven adaptive-learning systematic review	Systematic review of higher-education empirical studies	15 empirical studies, primarily 2020–2024; 73% published in 2023–2024	Adaptive learning platforms and AI-supported personalization	Reported academic-performance gains of approximately 15–25% and engagement improvements of up to 40%	Recurrent barriers were infrastructure limitations, faculty readiness, privacy, algorithmic bias, and underrepresentation of non-STEM disciplines
ChatGPT-based personalized adaptive learning in political science	Quasi-experimental empirical study; Chinese university	16-week undergraduate intervention; propensity-score matching and difference-in-differences	ChatGPT-supported adaptive learning paths, feedback, and interactive activities	Experimental students reportedly outperformed controls in learning efficiency, knowledge mastery, and satisfaction	Provides stronger evidence than perception-only surveys, but the available record does not specify sample size, effect sizes, confidence intervals, or subgroup equity results
AI-supported personalized learning review	Integrative literature review	24 publications from 2022–2026	Adaptive questioning, individualized feedback, differentiated pathways, and adaptive assessment	Associations were reported with engagement, self-regulated learning, and achievement; direct causal evidence for critical-thinking improvement remained limited	Outcomes varied by instructional design, learner autonomy, digital competence, and context; heterogeneity and lack of standardized quality appraisal limited generalizability
ML-based adaptive-learning systematic review	Systematic review	19 publications from 2015–2025	Collaborative filtering, Bayesian knowledge tracing, deep learning, reinforcement learning, NLP, and learning-style prediction	Reported engagement improvements of approximately 15–30%, alongside gains in performance and retention	Common concerns included algorithmic bias, lack of informed consent, opacity, and weak institutional governance, especially in under-resourced and Global South settings

Source	Type and context	Sample/design	AI intervention	Main outcomes	Equity/governance evidence
AI-supported learning tools empirical study	Mixed-methods intervention study	120 undergraduates; experimental and control groups; eight-week intervention	Adaptive learning platforms and intelligent tutoring systems	Experimental students showed greater improvement in academic performance, engagement, motivation, and satisfaction	Benefits were linked to real-time feedback and individualized pathways; barriers included privacy, digital divide, and teacher-training requirements
GenAI-based assessment and feedback study	Mixed-methods higher-education study	Undergraduate and postgraduate students across disciplines; sample size not reported in retrieved record	Generative AI assessment and feedback	Reported improvements in conceptual understanding, error correction, engagement, self-regulated learning, and satisfaction	Academic integrity, algorithmic bias, and ethical data use were identified as unresolved governance risks
AI-driven cross-cultural engineering adaptive platform	Empirical prototype implementation	Implemented across China, Indonesia, and the Arab world; sample details not reported	Culturally adaptive personalization in online engineering education	Reported improvements in engagement, retention, cultural relevance, satisfaction, and learning outcomes	Supports culture-aware and multilingual design, but the available record does not provide effect sizes, comparison groups, or detailed equity disaggregation

The adaptive-learning systematic review of 15 empirical studies, 73% of which were published in 2023–2024, reported academic-performance gains of approximately 15–25% and engagement improvements of up to 40% [24]. A separate systematic review of 19 publications from 2015–2025 reported engagement improvements of approximately 15–30% alongside gains in performance and retention [25]. A mixed-methods intervention study with 120 undergraduates over eight weeks found that experimental students showed greater improvement in academic performance, engagement, motivation, and satisfaction [26]. The ChatGPT-based political-science intervention, using a 16-week undergraduate design with propensity-score matching and difference-in-differences, reported superior experimental-group performance in learning efficiency, knowledge mastery, and satisfaction [27]. However, the integrative review of 24 publications concluded that direct evidence for improved critical thinking remains limited and that reported outcomes depend strongly on instructional design and learner autonomy [28].

The most frequently reported algorithmic approaches in adaptive systems include collaborative filtering, Bayesian knowledge tracing, deep learning, reinforcement learning, NLP, and learner-profile prediction [24,25]. The extracted policy parameters for adaptive systems include adaptation frequency (static, session-level, or real-time), difficulty-adjustment threshold, feedback delay, mastery threshold, weight assigned to prior achievement, behavior, and learner preference, degree of student control over recommended pathways, minimum human-review requirement, fairness constraints across demographic or access groups, and escalation rules for struggling or at-risk students. For chatbots and conversational agents, important design attributes include model and version, prompt/interface design, use of conversation history or memory, language capability, LMS integration, human-in-the-loop review, hallucination warnings and source verification, accessibility for students with disabilities, and availability to students with limited connectivity or paid-tool access.

The instructional policy optimization model extracted from the evidence incorporates multiple objectives and constraints. The objective function is to maximize learning gain, meaningful engagement, and student satisfaction while minimizing achievement disparities, privacy and security risk, hallucination and misinformation exposure, faculty workload, and inequitable access, while maintaining student agency and human oversight. Constraints include a minimum fairness-performance threshold, equal access across device and connectivity groups, human review for high-stakes assessment, consent and data-minimization requirements, explainability for consequential recommendations, alternative non-AI pathways, language and accessibility requirements, and periodic audit and stakeholder review. Optimization inputs include prior achievement, LMS activity, assessment performance, student preferences, course difficulty, engagement trajectory, self-efficacy and digital readiness, language and accessibility needs, resource availability, faculty workload, and equity and fairness metrics. A multi-objective policy function can be represented as $\max_{\pi} \lambda_1 L(\pi) + \lambda_2 E(\pi) + \lambda_3 S(\pi) - \lambda_4 G(\pi) - \lambda_5 P(\pi)$, where L is learning gain, E is engagement, S is satisfaction, G is subgroup disparity, P is privacy or implementation risk, and π is the instructional policy. Fairness constraints should be explicit, expressed as $|M_g - M_r| \leq \epsilon$, where M_g is the outcome for subgroup g , M_r is the reference-group outcome, and ϵ is the acceptable disparity threshold.

The equity dimensions identified across the retrieved studies include gender, domestic versus international or domicile status, academic level, discipline, computer experience, language availability, digital access, institutional infrastructure, disability and accessibility, cultural context, and STEM versus non-STEM representation. The Prince Sattam study found differences by gender, academic stage, field, and computer experience [22], and the UK perception study examined gender and domicile differences [21]. Reviews highlighted underrepresentation of non-STEM disciplines and weaker infrastructure in under-resourced and Global South settings [24,25]. The search evidence does not consistently report achievement gaps before and after intervention, differential treatment or recommendation quality, disability-specific outcomes, socioeconomic-status disaggregation, first-generation student outcomes, intersectional effects, language-group performance, or fairness metrics such as demographic parity or equal opportunity; these omissions should be coded as missing equity evidence rather than as evidence of equitable impact.

4.5 Polymer recycling, thermoplastic modification, and sustainable EV infrastructure

The polymer recycling evidence supports a provenance-linked extraction strategy organized around four themes: controlled architecture modification, smart stabilization, recycling processes, and recycle-versus-virgin comparison. As shown in Table 6, the controlled architecture modification routes span reactive extrusion, vitrimer nanocomposite formation, glass-fiber blending, and antioxidant-assisted metallocene isotactic polypropylene (iPP) recycling. A 2026 study on high melt strength polypropylene via reactive extrusion employed a peroxide initiator DHBP together with a TMPTA coagent to produce long-chain branched PP, and the modified virgin and recycled PP exhibited increased complex viscosity, storage modulus, melt elasticity, and strain-hardening, with recycled rPP5 achieving comparable foamability and mechanical behavior to virgin material [29]. A 2025 study on vitrimer nanocomposites derived from graphene oxide and post-consumer recycled polypropylene used styrene-assisted maleic-anhydride grafting followed by epoxide-enabled cross-linking to address the electrical and mechanical limitations of post-consumer recycled PP [30]. A 2024 study analyzed polymer mixtures derived from virgin and re-granulated PP with glass fibers, investigating industrial-scale reuse of post-industrial PP waste [31], while a 2022 study on metallo-

cene iPP established that antioxidant protection is central to retaining recycled-material performance [32].

Table 6. Controlled architecture modification routes for polypropylene.

Source	Modification route / architecture	Extracted parameters	Performance or reuse finding
Recycling of metallocene isotactic polypropylene: importance of antioxidants (2022)	Metallocene iPP; antioxidant-assisted recycling	Antioxidant identity, loading, Mw, Đ, tacticity, crystallinity, Tm, and mechanical values require extraction from the full text and supplementary data	Directly relevant to metallocene iPP recycling and antioxidant protection; antioxidant protection is central to retaining recycled-material performance
High Melt Strength Polypropylene via Reactive Extrusion (2026)	Reactive extrusion; long-chain branching; peroxide initiator DHBP plus TMPTA coagent	Architecture: long-chain branched PP; additives: DHBP and TMPTA; detailed branching content, residence time, temperature, Mw, Đ, and mechanical data were not exposed in the result	Modified virgin and recycled PP showed increased complex viscosity, storage modulus, melt elasticity, and strain-hardening; recycled rPP5 had comparable foamability and mechanical behavior to virgin material
Vitrimer nanocomposites derived from graphene oxide and post-consumer recycled polypropylene (2025)	Styrene-assisted maleic-anhydride grafting followed by epoxide-enabled crosslinking; graphene oxide nanocomposite	Architecture: grafted/crosslinked PCR-PP; exact graft density, additive loading, Mw, crystallinity, and thermal values require full-text extraction	Modification was designed to address the electrical and mechanical limitations of post-consumer recycled PP
Analysis of Selected Properties of Polymer Mixtures Derived from Virgin and Re-Granulated PP with Glass Fibers (2024)	Blending virgin PP, recycled PP, and glass fibers	Feedstock: post-industrial rPP; exact blend ratios, MFR, crystallinity, tensile, impact, and thermal values require full text	Industrial-scale reuse of post-industrial PP waste in virgin-PP/glass-fiber mixtures was investigated

The smart stabilization evidence, presented in Table 7, indicates that antioxidant selection is a decisive determinant of recyclate quality. A 2026 study using 0.2 wt.% propyl gallate antioxidant found that after five processing cycles, viscosity decreased by less than one order of magnitude with propyl gallate compared with nearly three orders of magnitude without antioxidant, and crystallinity decreased by only 8% [33]. A 2026 Journal of Applied Polymer Science study identified DSC-OIT and chemiluminescence OIT as useful indicators of residual antioxidant levels, with chemiluminescence total luminous intensity, chemiluminescence OIT, and DSC-OIT detecting early degradation more effectively than carbonyl index and thermal properties [34].

Table 7. Smart stabilization systems for polypropylene recycling.

Source	Stabilizer system	Loading	OIT / oxidation result	Recyclability implication
An Efficient Method for Recycling Polypropylene with the ... (2026)	Propyl gallate antioxidant	0.2 wt.%	OIT and oxidative-degradation indicators improved; exact OIT minutes were not provided in the retrieved result	After five processing cycles, viscosity decreased by less than one order of magnitude with propyl gallate, compared with nearly three orders of magnitude without antioxidant; crystallinity decreased by only 8%
Recycling of metallocene isotactic polypropylene: importance of antioxidants (2022)	Antioxidant protection of metallocene iPP	NR in retrieved result	Exact OIT and stabilizer-consumption data require full text	Establishes antioxidant selection as a key determinant of recycled iPP quality
The durability and recyclability of polypropylene (2026), Journal of Applied Polymer Science	Antioxidant-stabilized PP versus non-stabilized PP	NR in retrieved result	DSC-OIT and chemiluminescence OIT were identified as useful indicators of residual antioxidant levels	Chemiluminescence total luminous intensity, chemiluminescence OIT, and DSC-OIT detected early degradation more effectively than carbonyl index and thermal properties

The recycling process evidence, shown in Table 8, covers five studies employing repeated thermo-mechanical processing, mechanical grinding, dissolution-based recycling, shredding with material extrusion, and service-life simulation with remolding. The 2026 propyl gallate study used repeated thermomechanical processing over five cycles, with viscosity loss of less than one order of magnitude with stabilizer versus nearly three orders of magnitude to approximately 10 Pa.s without antioxidant [33]. A 2025 study on multiple recycling of PP composites with 10, 20, and 30 wt.% glass fiber used mechanical grinding and repeated recycling over five cycles, assessing grinding efficiency, particle-size distribution, bulk density, and recycled composite characteristics [35]. A 2023 study comparing mechanical and solvent-based recycling reported that dissolution-based recycling is a route toward near-virgin-quality recycled PP [36]. A 2024 study on green recycling for PP components by material extrusion used shredding and material-extrusion processing after service-life simulation [37], and a 2023 study on thermo-mechanical recyclability of additively manufactured PP and PLA parts used service-life simulation, shredding, extrusion, and remolding for repeated thermo-mechanical recycling [38].

Table 8. Recycling processes for polypropylene and composites.

Source	Feedstock	Method	Cycles / conditions	Extracted metric
An Efficient Method for Recycling Polypropylene with the ... (2026)	PP, antioxidant-stabilized and unstabilized	Repeated thermomechanical processing	Five processing cycles	With 0.2 wt.% propyl gallate, viscosity loss was less than one order of magnitude; without antioxidant, viscosity fell by nearly three orders of magnitude to approximately
The Multiple Recycling Process of Polypropylene Composites (2025)	PP composites with 10, 20, and 30 wt.% glass fiber	Mechanical grinding and repeated recycling	Five recycling cycles	Study assessed grinding efficiency, particle-size distribution, bulk density, and recycled composite characteristics
Complementary roles for mechanical and solvent-based recycling in low-carbon, circular polypropylene (2023)	Polypropylene waste	Mechanical recycling and dissolution-based recycling	Closed-loop life-cycle comparison	Dissolution-based recycling was reported as a route toward near-virgin-quality recycled PP; detailed energy and environmental values require the article's tables
Green Recycling for Polypropylene Components by Material Extrusion (2024)	Virgin and recycled PP	Shredding and material-extrusion processing	Service-life simulation followed by shredding and extrusion	Recycled PP was evaluated for rheology and mechanical performance; exact retention values were not available in the retrieved result
Thermo-Mechanical Recyclability of Additively Manufactured PP and PLA Parts (2023)	PP parts and support structures	Service-life simulation, shredding, extrusion, and remolding	Repeated thermo-mechanical recycling	Direct comparison of virgin and recycled PP/PLA parts; numerical property-retention values require full text

The recyclate-versus-virgin comparison, presented in Table 9, shows that recycled PP generally experiences degradation, with the 2026 reactive-extrusion study observing lower molecular weight and lower viscosity for recycled homopolymer rPP0 than for virgin PP0 [29]. PP recyclate MFR and shear viscosity were sufficiently variable to motivate predictive modeling of PP blends [39]. Reactive modification enabled recycled rPP5 to achieve comparable foamability and mechanical behavior to virgin material [29], and propyl-gallate stabilization limited crystallinity loss to 8% after several recycling cycles [33]. A systematic review reports that mechanically recycled PE/PP pellets had 22.6% lower CO₂ emissions than virgin production, and reports approximately \$0.3/kg for mechanical recycling, approximately \$1/kg for pyrolysis, approximately \$4/kg for solvolysis, and approximately \$8.4/kg for thermolysis [37]. One retrieved industry report estimates recycled thermoplastics at 60–75% of virgin-material prices, but this is not PP-specific and should be treated as a low-confidence market indicator [40].

Table 9. Recyclate versus virgin polypropylene attributes.

Attribute	Extracted evidence
Molecular-weight retention	Recycled PP generally experiences degradation; the 2026 reactive-extrusion study observed lower molecular weight and lower viscosity for recycled homopolymer rPP0 than for virgin PP0
MFR / viscosity	PP recyclate MFR and shear viscosity were sufficiently variable to motivate predictive modeling of PP blends
Mechanical retention	Reactive modification enabled recycled rPP5 to achieve comparable foamability and mechanical behavior to virgin material
Crystallinity retention	Propyl-gallate stabilization limited crystallinity loss to 8% after several recycling cycles
Application suitability	Reported or investigated applications include foamed materials, thermoforming packaging, additive-manufactured components, glass-fiber composites, and nanocomposites
Recycled-content ratio	Specific virgin-to-recyclate ratios were not available in the retrieved snippets; extract from the full texts of the blend and packaging studies
Closed-loop cycles	Five cycles were explicitly reported for the propyl-gallate study and the glass-fiber composite recycling study
Carbon footprint	A systematic review reports that mechanically recycled PE/PP pellets had 22.6% lower CO ₂ emissions than virgin production in the cited assessment
Recycling cost	The systematic review reports approximately \$0.3/kg for mechanical recycling, approximately \$1/kg for pyrolysis, approximately \$4/kg for solvolysis, and approximately \$8.4/kg for thermolysis; these values are review-level comparative figures and require boundary verification before techno-economic use
Recyclate price	One retrieved industry report estimates recycled thermoplastics at 60–75% of virgin-material prices, but this is not PP-specific and should be treated as a low-confidence market indicator

The EV infrastructure evidence is substantially weaker than the polymer recycling evidence. The retrieved results do not provide a technically usable solar-generation dataset: PV technology, rated panel efficiency, installed capacity, annual yield, temperature coefficient, degradation rate, tracking and soiling losses, inverter efficiency, and integrated PV-charging energy balance are all not reported. For wireless inductive EV charging, one technical article discusses an 11 kW home wireless system with 90–93% grid-to-battery efficiency for a well-aligned SAE J2954 system, compared with approximately 94% for plug-in Level 2 [41]. Other market reports claim 90% or greater and up to 92% by 2026 [42]. One market report claims 90% or greater efficiency within ± 15 cm lateral and ± 5 cm vertical misalignment, and resonant systems are reported to sustain at least 85% efficiency with ± 20 cm misalignment [42]. One market source describes tightly coupled systems as typically below 10 mm air gap and resonant systems as reaching up to 25 cm [43]. For infrastructure economics, an 11 kW home system including pad and vehicle receiver costs approximately \$2,500–\$3,500, installation and civil works approximately \$2,000–\$5,000, and total installed cost approximately \$5,000–\$12,000 per home charging bay [41]. One market report estimates \$3,000–\$5,000 per public charging point, while another estimates \$8,000–\$15,000 per complete medium-power location including civil works and distribution [43,41]. Wireless installations were reported as 15–25% more expensive than comparable wired systems [42], and one market report claims 40–50% lower connector replacement costs over a 10-year life [42]. No retrieved source reports all of PV technology and capacity, annual solar yield, storage capacity, wireless charging topology, end-to-end efficiency, CapEx, operating cost, and avoided emissions in one validated integrated system record.

5 Discussion

The synthesis carries substantial theoretical implications for how the anxiety-competence relationship should be modeled in applied linguistics. Our findings suggest that the field's prevailing emphasis on direct anxiety-reduction strategies may be misdirected, because the mediating architecture identified here indicates that anxiety exerts its influence largely through self-efficacy appraisals and perceived classroom climate. This reframing aligns with broader evidence that technical optimization metrics, whether statistical fairness criteria or engagement gains, remain insufficient without accountability structures [12]. Consequently, theoretical models that treat speaking anxiety as a unidimensional predictor of oral competence risk misspecification, and we argue for process-oriented frameworks in which audience evaluation resilience and effort allocation function as proximal mechanisms rather than epiphenomena.

Practically, these findings offer concrete guidance for language educators and assessment designers. Teachers can embed attributional retraining within collaborative speaking tasks, guiding learners to reinterpret anxiety as arising from controllable, strategy-related causes, and can deliberately frame corrective feedback as growth-oriented rather than evaluative, thereby targeting the missing function identified in our functional analysis. Assessment policymakers should adopt the multidimensional fairness framework synthesized here, since demographic parity alone may conceal genuine differences in opportunity and preparation [12]. Institutions deploying AI-mediated speaking tools must establish transparency and redress mechanisms, because learners with heightened audience evaluation concerns may otherwise be unable to contest automated judgments, reinforcing the very self-efficacy deficits that mediate the anxiety-competence pathway [14].

Several limitations constrain the interpretation of these findings. The evidence synthesis relied on retrieved snippets and abstracts for a substantial portion of sources, meaning that effect sizes, confidence intervals, and subgroup results were frequently unavailable, which limits the precision of our meta-analytic readiness assessment. Publication bias may inflate the reported benefits of adaptive learning interventions, since unsuccessful implementations are less likely to appear in indexed literature. The quality appraisal of included studies was necessarily subjective, particularly for prototype implementations and market reports whose methodological transparency varied widely. Furthermore, the cross-domain design, while productive for identifying structural patterns, means that domain-specific conclusions rest on heterogeneous evidence bases of unequal strength.

Future research should explore the proposed mediation model through intensive longitudinal designs that capture within-person fluctuations in self-efficacy and anxiety across authentic speaking tasks. There is a need for cluster-randomized trials testing whether classroom climate strengthening amplifies reattribution-self-efficacy pathways, and understudied areas include the intersection of disability, first-language background, and socioeconomic status in speaking assessment fairness. Future work should also examine how AI-mediated feedback systems can be designed to support rather than undermine audience evaluation resilience, and cross-cultural validation of the effort allocation mechanism across World Englishes contexts remains an important direction.

6 Conclusion

This synthesis set out to determine whether foreign language speaking anxiety influences oral communication competence directly or through mediating mechanisms, and the evidence assembled here supports the latter position. Linguistic and social self-efficacy function as parallel proximal mediators, while classroom climate operates as both mediator and contextual moderator that

conditions whether anxious learners engage with or withdraw from speaking tasks. The functional analysis sharpened this account by identifying audience evaluation resilience and effort allocation as the sub-components most in need of intervention, and teacher feedback valence for anxiety re-appraisal together with dynamic cognitive resource reallocation as the most consequential missing functions. Our principal contribution is a testable process model that reframes anxiety as a distal predictor whose influence is transmitted through modifiable mechanisms, thereby challenging intervention traditions that target anxiety reduction alone. The synthesis further establishes that these mechanisms operate within broader validity, equity, and accountability frameworks, since fairness constructs, governance mechanisms, and epistemic-justice considerations jointly determine whether pedagogical and technological interventions produce equitable outcomes.

Future research should subject the proposed model to intensive longitudinal and cluster-randomized testing, particularly to establish whether climate-strengthening practices amplify reattribution-self-efficacy pathways across diverse World Englishes contexts. The intersection of disability, first-language background, and socioeconomic status in speaking assessment fairness remains underexamined, as does the question of how AI-mediated feedback can be designed to sustain rather than erode audience evaluation resilience. Addressing these gaps would extend the model's explanatory reach and inform instructional and assessment practices that treat self-efficacy and classroom climate as legitimate targets of intervention in their own right.

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