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RESEARCH ARTICLE

Design, Practice, And Anxiety Reduction: A Meta-Analysis Of STEM-Oriented Interventions for Preservice Primary Teachers' Foreign Language Speaking Confidence

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Abstract

Foreign language speaking anxiety remains a persistent barrier to oral performance, participation, and communicative development across second and foreign language settings, with consequences that extend from learners' moment-to-moment classroom engagement to their long-term willingness to use the target language in professional contexts (Ansari, 2015; Bailey, 2020; Bashori et al., 2022). For preservice primary teachers, the stakes are amplified: they are expected to model communication, facilitate interaction, and create emotionally safe learning environments, yet many teacher candidates report anxiety when speaking in a foreign language and uncertainty about how to design learning tasks that support confident oral production. In parallel, teacher education has intensified attention to STEM-oriented design practices, which promote iterative problem-solving, collaboration, and authentic communication—conditions that may indirectly reshape affective barriers and strengthen self-efficacy beliefs related to performance (Bandura, 1997; Aslan-Tutak et al., 2017; DiFrancesca et al., 2014). This article develops a publication-ready meta-analytic synthesis focused on intervention studies that address speaking anxiety and speaking performance, while theoretically integrating mechanisms from STEM design-based teacher education and self-efficacy theory. Using established meta-analysis principles and methodological guidance, the study constructs an interpretive quantitative-qualitative synthesis pathway: defining eligibility boundaries, coding intervention characteristics, and interpreting patterns of effects and heterogeneity through a mechanism-focused lens (Arthur Jr. et al., 2001; Desimone, 2009; Bangert-Drowns et al., 2004). The results are presented as a descriptive meta-analytic narrative that traces how particular intervention logics—flipped learning, web-based speaking practice, remote tasks, gamified language learning, voice-based interaction, dynamic assessment, and embodied methods—operate as anxiety-reduction pathways, and how STEM-oriented design practice in preservice preparation may amplify those pathways by providing mastery experiences, peer collaboration, and professional identity development (Abdullah et al., 2021; Abuhussein et al., 2023; Ali, 2022; Anton, 2009; Blackmore et al., 2018). The discussion advances a practical framework for designing preservice programs that deliberately connect STEM design pedagogy and language speaking interventions to reduce anxiety and strengthen speaking confidence, while acknowledging limitations of evidence transfer across populations and the methodological constraints typical of intervention research (Desimone, 2009; Becker & Park, 2011).

KEYWORDS
speaking anxiety; preservice teachers; STEM design; intervention studies; self-efficacy; meta-analysis; oral communication.

INTRODUCTION

Foreign language speaking is a uniquely exposed form of performance. Unlike reading or private writing, speaking places the learner's developing competence in public view, often under time pressure, and in the presence of peers whose reactions can be interpreted as evaluation. This combination of immediacy and social visibility makes speaking a frequent locus of anxiety in ESL/EFL contexts and a consistent target for pedagogical intervention (Ansari, 2015; Bailey, 2020). Speaking anxiety is not merely discomfort; it can shape what learners attempt, how much they practice, and whether they develop communicative habits necessary for functional proficiency. When learners avoid speaking opportunities, they reduce the very input–output cycles that support improvement, potentially reinforcing a loop of low confidence and limited progress (Bashori et al., 2022; Bailey, 2020).

For preservice primary teachers, speaking anxiety can be especially consequential because teacher education aims not only to build personal competence but also to prepare candidates to lead classrooms. The preservice phase is where candidates form professional identities, rehearse instructional roles, and internalize norms of practice that later influence their teaching (Blackmore et al., 2018). If teacher candidates experience persistent foreign language speaking anxiety, they may restrict their own communicative participation, underuse interactive methods, and feel less prepared to model language use—especially in contexts where primary teachers are expected to integrate cross-curricular competencies and communicative approaches.

At the same time, teacher education worldwide has pushed toward STEM-oriented learning, frequently framed as a way to develop problem-solving, creativity, collaboration, and real-world relevance (Bybee, 2010; Blackley & Howell, 2015). In preservice preparation, STEM design experiences often involve collaborative planning, iterative engineering design, reflection on pedagogy, and the challenge of explaining ideas clearly to others—activities that resemble authentic communication demands (DiFrancesca et al., 2014; Ayaz & Sarıkaya, 2019). Although these STEM experiences are typically justified in terms of science and engineering learning, they also involve affective and motivational dynamics. Specifically, design-based learning can generate mastery experiences, peer support, and identity-affirming moments that are central to self-efficacy development (Bandura, 1997). Because self-efficacy influences persistence, risk-taking, and resilience in performance situations, it offers a theoretical bridge between STEM design practice and language speaking confidence (Bandura, 1997).

A key challenge is that the literatures often evolve in parallel. Research on STEM teacher education documents shifts in awareness, pedagogical practice, and identity through collaborative STEM preparation (Aslan-Tutak et al., 2017; Berisha & Vula, 2021; Bakırcı & Karışan, 2018). Meanwhile, language education research investigates speaking anxiety reduction through interventions such as flipped learning, remote speaking tasks, web-based practice, gamified mobile-assisted language learning, and voice-based technologies (Abdullah et al., 2021; Abuhussein et al., 2023; Ali, 2022; Bashori et al., 2022; Azizimajd, 2023). What remains underdeveloped is a mechanism-centered integration that explains how preservice teacher design practices—especially those aligned with STEM—can be leveraged to strengthen oral confidence and reduce speaking anxiety, and how intervention evidence can be synthesized meta-analytically to guide program design.

Meta-analysis and systematic synthesis are particularly valuable where intervention evidence is diverse and sometimes difficult to compare directly. Meta-analysis offers a structured method for aggregating effects, examining variability, and interpreting patterns, provided that the procedures for inclusion, coding, and analysis are transparent and conceptually coherent (Arthur Jr. et al., 2001; Bangert-Drowns et al., 2004). At the same time, education intervention research must address issues of conceptualization and measurement; impact studies can be weakened by imprecise definitions of what the "intervention" actually is and how it is implemented (Desimone, 2009). For STEM education, meta-analytic work has already been used to evaluate integrative approaches across STEM subjects, highlighting both promise and challenges in comparing diverse instructional models (Becker & Park, 2011). This suggests the feasibility of meta-

analytic thinking for STEM-related pedagogical questions, while also cautioning that heterogeneity is often substantial and must be interpreted rather than ignored (Becker & Park, 2011).

This article therefore positions itself at the intersection of three concerns: (1) foreign language speaking anxiety and the effectiveness of anxiety-reduction interventions; (2) preservice teacher STEM design experiences as contexts for building self-efficacy and professional identity; and (3) meta-analytic synthesis as a method for producing program-relevant conclusions from diverse intervention evidence (Bandura, 1997; Aslan-Tutak et al., 2017; Arthur Jr. et al., 2001). The core argument is that many speaking-anxiety interventions work not only because they provide "more practice," but because they reshape the psychological conditions of speaking by altering perceived threat, increasing perceived control, and enabling repeated mastery experiences. STEM-oriented design practice, when intentionally coupled with language-speaking interventions, may intensify these mechanisms by normalizing iterative trial, public explanation, and collaborative problem-solving—all of which can reduce fear of error and increase tolerance for communicative imperfection (Bandura, 1997; DiFrancesca et al., 2014; Blackmore et al., 2018).

The study addresses three guiding questions aligned with meta-analytic reasoning:

First, what intervention types in the provided evidence base appear most consistently associated with reductions in foreign language speaking anxiety and improvements in oral performance (Abdullah et al., 2021; Abuhussein et al., 2023; Ali, 2022; Bashori et al., 2022)?

Second, what theoretical mechanisms—particularly self-efficacy—can explain why these interventions may work across contexts and populations (Bandura, 1997)?

Third, how can preservice primary teacher STEM design experiences be structured to amplify anxiety-reduction mechanisms and translate them into durable speaking confidence relevant to future teaching roles (Aslan-Tutak et al., 2017; Ayaz & Sarıkaya, 2019; Blackmore et al., 2018)?

METHODOLOGY

This study is framed as a meta-analytic synthesis with mechanism-oriented interpretation. Because the provided evidence base includes both STEM teacher education studies and language-speaking anxiety interventions—some of which are not explicitly STEM-focused—the method follows two complementary tracks: a meta-analytic logic for intervention evidence in language speaking anxiety, and an interpretive integration with STEM preservice design literature to build a coherent program framework (Arthur Jr. et al., 2001; Desimone, 2009).

Meta-analytic design logic and scope. Meta-analysis requires explicit definitions of (a) the phenomenon of interest, (b) eligible study designs, (c) target population boundaries, (d) outcome measures, and (e) analytic approach for aggregating or comparing effects (Arthur Jr. et al., 2001; Bangert-Drowns et al., 2004). In this article, the phenomenon of interest is foreign language speaking anxiety reduction and speaking confidence improvement through interventions. Speaking confidence is treated as the functional inverse of anxiety-driven avoidance and as the positive capacity to participate in speaking tasks with manageable affective load (Ansari, 2015; Bailey, 2020). Outcomes can include reported speaking anxiety, oral performance indicators, enjoyment, engagement, and related affective or behavioral indicators, as long as they are tied to speaking and are assessed before and after an intervention (Abdullah et al., 2021; Ali, 2022; Akdağ-Çimen & Çeşme, 2022).

The design acknowledges that intervention studies vary in format and measurement. For example, studies may use flipped learning to shift practice time and autonomy (Abdullah et al., 2021; Amiryousefi, 2019), employ remote speaking tasks to change the social context of speaking (Abuhussein et al., 2023), use web-based environments that alter exposure and feedback conditions (Bashori et al., 2022), or introduce gamified mobile learning to increase enjoyment and persistence (Ali, 2022). The methodology therefore emphasizes coding and interpretation of intervention components rather than treating all interventions as equivalent. This is consistent with calls for better conceptualization and measurement in professional development and impact studies, where "what the program is" must be clearly described to interpret outcomes (Desimone, 2009).

Eligibility criteria. Within the provided reference set, "intervention studies" include empirical work where an instructional, technological, or assessment approach is introduced with the purpose or measured effect of changing speaking anxiety, speaking performance, or related speaking outcomes. This includes flipped classroom interventions

(Abdullah et al., 2021; Amiryousefi, 2019), technology-mediated speaking tasks (Aktaş, 2023; Azizimajd, 2023), remote speaking tasks (Abuhussein et al., 2023), gamified MALL applications (Ali, 2022), and web-based language learning environments (Bashori et al., 2022). It also includes dynamic assessment as a pedagogical assessment intervention that can reshape learners' perceptions of evaluation and support (Anton, 2009). Studies that are primarily descriptive or conceptual, such as holistic discussions of speaking anxiety without intervention evaluation, serve as theoretical context rather than effect evidence (Ansari, 2015; Bailey, 2020).

Because the article's title foregrounds preservice primary teachers, an ideal meta-analysis would restrict the sample to preservice teacher participants. However, the provided language-anxiety interventions include varied learner populations (e.g., EFL learners, preparatory students, young learners). Rather than excluding these sources, the methodology adopts a bounded generalization approach: interventions are synthesized for their mechanism logic, then interpreted for transferability to preservice primary teacher contexts, using preservice STEM and teacher identity literature to guide inference (Blackmore et al., 2018; Depaepe & König, 2018). This strategy is aligned with the reality that education intervention evidence often requires careful transfer reasoning rather than direct one-to-one generalization (Desimone, 2009).

Coding framework for interventions. Meta-analytic practice depends on a coding scheme that captures intervention characteristics likely to influence outcomes (Arthur Jr. et al., 2001; Bangert-Drowns et al., 2004). Here, each intervention is coded conceptually on:

1. Exposure structure (how speaking opportunities are distributed, repeated, and scaffolded), as in flipped learning that increases practice time or shifts cognitive load (Abdullah et al., 2021; Amiryousefi, 2019).

2. Social risk management (how the intervention reduces perceived threat of negative evaluation), such as remote tasks that allow practice without immediate peer scrutiny (Abuhussein et al., 2023) or web-based environments that can normalize error and repetition (Bashori et al., 2022).

3. Feedback and assessment format (how learners receive guidance and how evaluation is framed), including dynamic assessment that integrates support into assessment to reduce anxiety about judgment (Anton, 2009).

4. Motivational affordances (enjoyment, engagement, game-like elements) that may reduce anxiety by changing the emotional tone of practice (Ali, 2022).

5. Embodied or communicative method (e.g., TPR, CLT, drama) that changes how learners experience speaking and interaction (Akdağ-Çimen & Çeşme, 2022; Aykac & Cetinkaya, 2013).

6. Technology modality (Web 2.0 tools, voice-based chatbots) that changes immediacy, audience, and rehearsal conditions (Aktaş, 2023; Azizimajd, 2023).

Integration with STEM preservice design practice. STEM-focused references are used to theorize how preservice teachers' design experiences provide parallel conditions that support anxiety reduction and confidence building: collaborative learning, iterative design, public explanation of ideas, and professional identity development (Aslan-Tutak et al., 2017; DiFrancesca et al., 2014; Blackmore et al., 2018). The method therefore includes an interpretive bridge built from self-efficacy theory, which explains how mastery experiences and social persuasion can strengthen perceived capability (Bandura, 1997). Preservice STEM awareness and practice development studies inform how teacher education can structure learning experiences that change beliefs and classroom readiness (Bakırcı & Karışan, 2018; Berisha & Vula, 2021).

Analytic strategy and presentation. In a full statistical meta-analysis, effect sizes would be computed and aggregated, potentially using software-based procedures. The current article, constrained to the provided reference set and presented as a publication-ready synthesis, reports results as a descriptive meta-analytic narrative: identifying convergence and divergence in intervention logic and interpreting heterogeneity through mechanism categories rather than through numerical aggregation (Arthur Jr. et al., 2001; Becker & Park, 2011). This approach mirrors how meta-analytic insights can be meaningfully communicated when quantitative aggregation is limited by differences in measures, populations, and reporting practices (Bangert-Drowns et al., 2004; Desimone, 2009).

RESULTS

The results are organized around mechanism categories derived from the intervention evidence base and interpreted

in relation to preservice teacher STEM design conditions. The central finding is that interventions that reduce speaking anxiety do so by systematically changing the learner's relationship to speaking practice: they increase controllability, reduce social threat, intensify repetition, and reframe assessment. These mechanisms map directly onto self-efficacy development, which is strengthened when individuals experience successful performance under manageable conditions and interpret that success as evidence of capability (Bandura, 1997).

Intervention pathway 1: Restructuring practice through flipped learning to increase control and repetition. Flipped learning interventions are consistently theorized as changing where and when practice happens. Instead of concentrating performance in teacher-fronted class time, flipped models shift content exposure to outside class and reserve class time for interaction, problem-solving, and applied practice (Abdullah et al., 2021; Amiryousefi, 2019). From an anxiety perspective, this restructuring can lower the perceived stakes of initial exposure. Learners can first encounter language input privately, repeat it, and prepare for speaking tasks with less time pressure, which can reduce the fear of being caught unprepared in public (Abdullah et al., 2021; Amiryousefi, 2019).

Mechanistically, flipped learning increases perceived control—learners decide when to pause, replay, or rehearse—creating conditions conducive to mastery experiences. When learners arrive in class with a sense of preparation, they may interpret participation as less risky and more achievable, which supports confidence development (Bandura, 1997; Abdullah et al., 2021). Over time, repeated manageable successes can reduce anxiety because the learner's prediction of failure becomes less plausible. The point is not that flipped learning "removes difficulty," but that it redistributes difficulty across time and context, making it psychologically tolerable and pedagogically productive (Amiryousefi, 2019; Bailey, 2020).

For preservice teachers, flipped structures align with professional realities: teachers often need to prepare and rehearse before public performance. If preservice candidates practice speaking in structured flipped routines, they not only reduce anxiety but also develop professional habits of preparation and reflection that are compatible with teacher identity development (Blackmore et al., 2018).

Intervention pathway 2: Remote speaking tasks and audience modulation to reduce social-evaluative threat. Remote speaking tasks alter the social context of speaking. Instead of speaking spontaneously in front of peers, learners engage in tasks that may be recorded, submitted, or conducted in a less immediately evaluative environment (Abuhussein et al., 2023). This matters because speaking anxiety is often intensified by fear of negative evaluation—fear of being judged for accent, errors, or hesitation. When the immediate audience is reduced or changed, the perceived threat can decline, enabling learners to attempt speech more freely and to focus on communication rather than on self-monitoring.

Remote tasks also support repetition. Learners can re-record or redo tasks, which creates iterative mastery experiences. Importantly, this does not necessarily remove accountability; rather, it reframes accountability around improvement and completion, not instantaneous perfection (Abuhussein et al., 2023; Bandura, 1997). When learners can attempt a speaking task multiple times, they can gradually approach a performance that meets their own standards, which builds competence and reduces anxiety about failure.

In preservice teacher preparation, remote speaking tasks can be integrated into STEM design projects by requiring candidates to produce short explanations of their design rationales, reflections on classroom applications, or micro-teaching segments. Because STEM design education already uses iterative development—draft, test, revise—remote speaking tasks fit naturally. This is a key integration point: the design culture normalizes revision, which can help candidates reinterpret speaking not as a single high-stakes event but as an improvable performance (DiFrancesca et al., 2014; Aslan-Tutak et al., 2017).

Intervention pathway 3: Web-based environments and technology-mediated rehearsal to normalize error and expand practice volume. Web-based language learning environments are associated with changes in exposure, practice opportunities, and the emotional tone of speaking practice, with evidence indicating relationships between web-based learning and speaking anxiety dynamics (Bashori et al., 2022). Web-based modalities can reduce anxiety by providing private rehearsal space, flexible pacing, and sometimes less intimidating feedback. At the same time, technology does not automatically reduce anxiety; it can also introduce new anxieties (e.g., technical failure). However, when designed as a supportive practice environment, it can increase practice volume and reduce avoidance—two key conditions for anxiety reduction (Bailey, 2020; Bashori et al., 2022).

Web 2.0 tools used for speaking practice can further reshape the speaking experience by offering playful or semi-anonymous forms of oral production, such as avatar-based speaking or creative presentation formats. Technology-based applications have been examined for their effects on speaking skills and speaking anxiety, suggesting that modality and task design matter for affective outcomes (Aktaş, 2023). A central mechanism is that technology can shift focus from the speaker's self-consciousness to the task artifact, which reduces perceived personal exposure.

In STEM preservice contexts, web-based environments can serve dual functions: supporting candidates' STEM pedagogy development while also providing structured opportunities to speak in the target language about concrete artifacts (designs, lesson plans, prototypes). Speaking about tangible work products can reduce anxiety because attention is shared between speaker and object, and because the content is meaningful and grounded rather than abstract. This aligns with STEM education's emphasis on authentic contexts and integrated learning (Bybee, 2010; Charette, 2015).

Intervention pathway 4: Gamified mobile-assisted language learning and affective reorientation through enjoyment. Gamified applications in language learning are often positioned as ways to increase motivation, enjoyment, and engagement, while reducing negative affect such as speaking anxiety (Ali, 2022). Enjoyment is not a superficial benefit; it changes persistence. When learners experience speaking practice as enjoyable, they engage more often, which increases the likelihood of developing competence and confidence. Moreover, gamification can reframe errors as part of play rather than as personal failure, reducing the shame component of speaking anxiety (Ali, 2022; Ansari, 2015).

For preservice teachers, gamified speaking practice can be aligned with STEM design experiences by using game-like challenges around explaining design choices, collaborating in teams, or presenting solutions within time constraints. When teacher candidates learn to experience performance as a manageable challenge rather than as a threat, they develop professional resilience. This resonates with self-efficacy theory: individuals persist when they believe effort can lead to improvement and when they interpret challenges as surmountable (Bandura, 1997).

Intervention pathway 5: Embodied and communicative methods that change the felt experience of speaking. Interventions rooted in communicative and embodied approaches—such as combining Total Physical Response (TPR) and Communicative Language Teaching (CLT)—have been studied for impacts on speaking anxiety and oral outcomes (Akdağ-Çimen & Çeşme, 2022). The mechanism here involves altering the experience of speaking from purely verbal performance to integrated action, interaction, and meaning-making. When speaking is tied to movement, role, or structured interaction, learners may experience less self-focused attention and more task-focused engagement, which can reduce anxiety.

Creative drama activities have also been examined for their effects on preservice teachers' speaking skills, suggesting that performance-based pedagogies can support oral development in teacher education contexts (Aykac & Cetinkaya, 2013). Drama and role-based speaking allow learners to "speak as someone else," which can reduce personal vulnerability and create safe distance while practicing language. For preservice teachers, role-based speaking can be directly professional: micro-teaching, classroom talk simulations, and parent–teacher communication role-plays can all be designed to reduce anxiety through repeated, structured rehearsal.

These methods parallel STEM design practices that require collaborative talk, peer negotiation, and presentation. Both domains normalize trial, error, and iterative improvement. This convergence supports the argument that STEM design experiences can be used as a psychologically supportive platform for language speaking confidence building, provided that the language speaking component is intentionally designed and scaffolded (Aslan-Tutak et al., 2017; DiFrancesca et al., 2014).

Intervention pathway 6: Dynamic assessment as a reframe of evaluation and a reduction of threat. Assessment is a major driver of speaking anxiety because speaking is often judged in real time, and learners may interpret assessment as a measure of personal worth rather than as feedback for growth (Ansari, 2015). Dynamic assessment approaches integrate mediation and support into assessment, shifting the meaning of evaluation from "judgment" to "development" (Anton, 2009). When learners perceive assessment as supportive, anxiety can decrease because the threat of failure is softened by the expectation of guidance.

For preservice teachers, dynamic assessment aligns with the pedagogical stance they are expected to adopt with children: assessment as learning support. When candidates experience supportive assessment themselves, they may become more

confident speakers and also more capable of designing low-threat speaking tasks for their future classrooms. This suggests a dual benefit: anxiety reduction and pedagogical skill development (Anton, 2009; Bailey, 2020).

STEM preservice design practice as an amplifier of anxiety-reduction mechanisms. STEM teacher education literature indicates that collaborative learning to teach STEM can change preservice teachers' awareness and readiness, and that design-based science teaching can shape perceptions toward STEM disciplines (Aslan-Tutak et al., 2017; Ayaz & Sarıkaya, 2019). Preservice STEM development also includes attention to pedagogical practices and professional growth (Berisha & Vula, 2021). These experiences matter for language speaking confidence because they create repeated opportunities to explain, justify, and present ideas in socially meaningful contexts.

Self-efficacy theory provides the integrative logic: when preservice teachers repeatedly succeed in communicating about design tasks—especially under supportive peer collaboration—they build beliefs that they can perform communicative tasks. Those beliefs can generalize to foreign language speaking if the speaking tasks are connected to meaningful content and scaffolded appropriately (Bandura, 1997). Moreover, professional identity development in teaching is influenced by experiences of competence. When candidates experience themselves as capable communicators, they may adopt more confident teacher identities, which further stabilizes their willingness to speak and teach interactively (Blackmore et al., 2018).

DISCUSSION

The synthesis indicates that speaking anxiety reduction is best understood as a design problem rather than as an individual deficit. Interventions work when they change task ecology: pacing, audience, feedback, motivational framing, and the meaning of evaluation. This section interprets these findings, addresses counter-arguments, and outlines implications for preservice primary teacher programs that aim to integrate STEM design practice with foreign language speaking confidence development.

Reinterpreting speaking anxiety as an interaction between person, task, and evaluation climate. Speaking anxiety is often described as an internal feeling, but intervention evidence suggests it is responsive to external design conditions. When speaking tasks are structured to reduce time pressure, allow rehearsal, and provide supportive feedback, anxiety can decline because the environment becomes less threatening and more controllable (Abdullah et al., 2021; Abuhussein et al., 2023; Anton, 2009). This aligns with the broader view that speaking development requires safe opportunities for trial and error, not merely exposure to linguistic forms (Bailey, 2020).

From a self-efficacy perspective, the key is not eliminating challenge but sequencing challenge so that learners experience success early enough to build momentum. This is the foundational logic of mastery experiences: successful performance strengthens perceived capability, which increases willingness to attempt more difficult tasks (Bandura, 1997). When interventions produce manageable success, learners revise their expectations about speaking from "I will fail" to "I can improve." That expectation shift is a plausible mechanism behind anxiety reduction across different modalities, whether flipped, remote, gamified, or assessment-reframed (Abdullah et al., 2021; Ali, 2022; Anton, 2009).

Why STEM design practice is a credible partner for speaking confidence development in preservice education. STEM design learning already cultivates a culture of iteration: prototypes are tested, revised, and improved. This cultural norm reduces the stigma of error, which is central to anxiety. When preservice teachers internalize design norms, they may become more tolerant of imperfection in their own performance, including language performance. Furthermore, STEM design experiences are collaborative; peer discussion and shared problem-solving provide social persuasion and vicarious experiences—additional pathways through which self-efficacy can strengthen (Bandura, 1997; Aslan-Tutak et al., 2017).

STEM teacher education research shows that preservice teachers' awareness and pedagogical practice can change through collaborative learning and targeted preparation (Aslan-Tutak et al., 2017; Berisha & Vula, 2021). If speaking confidence is treated as part of pedagogical readiness—particularly for future teachers who must model communication—then integrating speaking interventions into STEM design work becomes a logical programmatic move rather than an add-on. For instance, engineering design-based science teaching shifts candidates' perceptions of STEM disciplines (Ayaz & Sarıkaya, 2019); similarly, design-based speaking tasks can shift candidates' perceptions of speaking from a feared performance to a tool for explanation, persuasion, and teaching.

A program framework for preservice primary teachers: aligning intervention mechanisms with design pedagogy. The synthesis supports an integrated program framework with five design principles, each grounded in the intervention evidence and STEM teacher education logic.

First, increase low-threat speaking volume through structured rehearsal, using flipped or remote speaking tasks early in the program to build baseline confidence (Abdullah et al., 2021; Abuhussein et al., 2023). In STEM design courses, this could involve short recorded "design diary" reflections in the target language—brief, repeated, and non-punitive.

Second, use technology to modulate audience and normalize repetition through web-based or Web 2.0 tools, allowing candidates to practice speaking about concrete design artifacts and lesson plans (Aktaş, 2023; Bashori et al., 2022). The focus on artifacts reduces self-consciousness and increases communicative meaningfulness.

Third, leverage motivational affordances—gamified challenges and enjoyment-oriented tasks—to reduce avoidance and sustain practice (Ali, 2022). In design teams, this could involve structured "pitch" challenges where teams present solutions in a playful format.

Fourth, embed embodied and role-based speaking pedagogies (drama, CLT-oriented interaction) to change the felt experience of speaking and develop classroom-relevant oral routines (Akdağ-Çimen & Çeşme, 2022; Aykac & Cetinkaya, 2013). For preservice teachers, role plays can mirror real teacher talk: explaining instructions, giving feedback, managing group work.

Fifth, reframe evaluation through dynamic assessment principles, where speaking is assessed with mediation and improvement feedback rather than as a one-shot judgment (Anton, 2009). This aligns with teacher education values and reduces fear-driven silence.

These principles are consistent with the idea that educational impact depends on conceptual clarity and implementation quality. Programs must specify what the intervention is, how it is enacted, and how outcomes are measured; otherwise, conclusions become ambiguous (Desimone, 2009).

Counter-arguments and limitations. A central counter-argument is that the language intervention evidence base includes populations that may not match preservice primary teachers. Indeed, some interventions target EFL preparatory students or young learners, and the motivational and social dynamics may differ. However, the synthesis focuses on mechanisms that plausibly transfer across populations: control of practice, reduction of evaluative threat, supportive feedback, and increased mastery experiences. These mechanisms are not population-specific; they are features of learning environments (Bandura, 1997; Bailey, 2020). Transferability still requires adaptation, but the program logic remains relevant.

Another counter-argument concerns STEM: STEM design experiences might increase cognitive load, potentially increasing anxiety rather than reducing it. If candidates are overwhelmed by technical demands, adding foreign language speaking requirements could intensify stress. This risk underscores the need for careful sequencing: early speaking tasks should be low-stakes, brief, and supportive. Over time, as competence grows, speaking demands can increase. This is precisely the mastery sequencing logic suggested by self-efficacy theory (Bandura, 1997).

A further limitation involves heterogeneity and measurement differences. Meta-analytic synthesis is strongest when outcomes are comparable, yet speaking anxiety measures and speaking performance indicators differ across studies. Methodological guidance for meta-analysis emphasizes careful coding, transparent criteria, and cautious interpretation when heterogeneity is high (Arthur Jr. et al., 2001; Bangert-Drowns et al., 2004). The current article therefore emphasizes mechanism synthesis rather than numeric aggregation. This approach is compatible with STEM meta-analytic work that recognizes the challenge of comparing diverse integrative approaches (Becker & Park, 2011).

Future scope. Future research can conduct a focused meta-analysis restricted to preservice teacher samples, computing effect sizes for speaking anxiety and speaking performance outcomes and examining moderators such as technology modality, task type, duration, and assessment format (Arthur Jr. et al., 2001). Additionally, future intervention studies can explicitly combine STEM design-based teacher education with language speaking confidence interventions, testing whether design pedagogy amplifies anxiety reduction by increasing mastery experiences and collaborative support (Aslan-Tutak et al., 2017; Bandura, 1997). Researchers can also examine professional identity outcomes: whether increased speaking confidence translates into more interactive teaching approaches during practicum, connecting to evidence that

trainee experiences shape professional identity development (Blackmore et al., 2018).

CONCLUSION

This meta-analytic synthesis argues that foreign language speaking anxiety reduction is best achieved through intentional design of practice conditions: increasing controllability, reducing social-evaluative threat, enabling repetition, reframing assessment, and sustaining motivation. Across diverse interventions—flipped learning, remote speaking tasks, web-based practice, Web 2.0 tools, gamified mobile learning, voice-based interaction, embodied communicative methods, and dynamic assessment—the shared mechanism is the creation of repeated, manageable speaking successes that strengthen self-efficacy and reduce avoidance (Abdullah et al., 2021; Abuhussein et al., 2023; Ali, 2022; Anton, 2009; Bandura, 1997).

For preservice primary teachers, the synthesis highlights a strategic opportunity: integrate these anxiety-reduction pathways into STEM-oriented design practice. STEM design experiences normalize iteration, collaborative explanation, and artifact-based communication—conditions that align with self-efficacy development and can be harnessed to build speaking confidence that is professionally meaningful (Aslan-Tutak et al., 2017; DiFrancesca et al., 2014; Blackmore et al., 2018). Rather than treating speaking anxiety as an isolated language problem, teacher education programs can position speaking confidence as a professional competence developed through coherent, supportive, design-based learning experiences.

While limitations remain—particularly regarding population matching and outcome measurement comparability—the mechanism-centered conclusions offer actionable guidance: design preservice pathways that begin with low-threat speaking rehearsal, use technology to expand practice and modulate audience, incorporate enjoyment and role-based pedagogy to reduce fear, and assess speaking through supportive, development-oriented approaches. Such integration not only reduces anxiety but also prepares future primary teachers to model communication and lead classrooms where learners experience speaking as a skill to build, not a performance to fear (Bailey, 2020; Bandura, 1997).

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