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TPACK Development in Preservice Teacher Education: How Course Design and Self-Efficacy Beliefs Shape Technology Integration

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Abstract: Preservice programs still struggle to prepare teachers who can integrate technology into subject-matter instruction with any real sophistication. TPACK provides a useful lens for understanding why this happens, yet we know surprisingly little about how specific course design choices influence TPACK growth, or how self-efficacy interacts with that process over a full semester. We tracked 55 preservice teachers through a 14-week technology integration course built around extended duration, active learning, collaboration, reflection, and disciplinary grounding. Using an adapted Schmidt et al. TPACK survey and the TISE scale at three time points, we found significant gains across every subdomain. The largest shifts occurred in integrated TPACK (d = 1.61), TPK (d = 1.50), and technology integration self-efficacy (d = 1.53). Open-ended responses clustered around four ideas: practical relevance, collaborative inquiry, reflective growth, and disciplinary grounding. Courses that embed technology work inside authentic disciplinary tasks not as an add on produce measurable, practically meaningful change in both knowledge and confidence. We discuss what this means for program structure.

Keywords: TPACK, preservice teacher education, technology integration, self-efficacy.

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INTRODUCTION

For two decades, teacher educators have faced a stubborn problem: preservice teachers arrive with access to digital tools but leave without knowing how to use them to advance student learning. The gap is not about access. K–12 classrooms are saturated with learning management systems, adaptive platforms, and mobile devices. The problem is that preservice teachers rarely encounter technology as something that reshapes what content looks like, how pedagogy functions, or what student engagement means in a specific subject area (Tondeur et al., 2023; Valtonen et al., 2024).

Mishra and Koehler's (2006) TPACK framework was an attempt to move beyond "tool training." By extending Shulman (1986), they argued that effective technology integration emerges from the interplay of content, pedagogy, and technology—not from mastering each in isolation. The seven-component model has since dominated educational technology scholarship. But in preservice contexts, results have been uneven. Early reviews found that technology courses often isolated TK from disciplinary content and pedagogical reasoning, producing modest, short-lived gains (Abbitt, 2011; Angeli & Valanides, 2009). More recent work has pushed for design-based, practice-embedded experiences that situate skill development inside authentic teaching contexts (Koh & Chai, 2024; Mouza & Karchmer-Klein, 2021).

Self-efficacy matters here too. Bandura (1997) made the case decades ago that beliefs about one's own capacity predict behavior better than actual knowledge alone. In technology integration research, that pattern holds: teachers with stronger self-efficacy use technology more frequently and more intentionally (Knezek & Christensen, 2016; Zelkowski et al., 2023). Yet the relationship is messy. Abbitt (2011) found correlations between self-efficacy and TPACK, but directionality remained unclear. Zelkowski et al. (2023) showed that self-efficacy mediates between TPACK knowledge and observed lesson quality—two preservice teachers with identical survey scores produce different classroom outcomes depending on confidence. Valtonen et al. (2024) added a temporal wrinkle: self-efficacy often lags behind knowledge early in training, then accelerates once participants implement technology in real classrooms.

Three gaps in the literature motivated this study. First, most intervention research relies on short workshops or single-course snapshots rather than sustained semester-length experiences with multiple measurement points. Second, few studies track TPACK and self-efficacy together over time, which makes it hard to tell whether gains reflect knowledge, motivation, or both. Third, mixed-methods designs that connect quantitative trajectories to how participants actually describe their learning remain scarce.

Mishra and Koehler (2006) developed TPACK out of frustration with training models that treated technology as a neutral add-on to existing teaching practice. Shulman (1986) had already established that teaching expertise requires a distinct form of pedagogical reasoning about content; Mishra and Koehler extended that logic to argue that technology integration is similarly irreducible. TPACK is not the sum of three knowledge bases but an emergent, situated competence that looks different across teachers, disciplines, and classroom contexts.

The framework has attracted substantial criticism, much of it warranted. Archambault and Barnett (2010) and Voogt et al. (2013) questioned whether self-report surveys can capture a construct that the theory itself defines as performative and context-dependent. Angeli and Valanides (2013) challenged the model's implicit disciplinary neutrality, arguing that technology interacts with science content differently than with literacy or the arts in ways the original framework under-theorized. Recent extensions have tried to address these limitations. Blömeke et al. (2022) reconceptualized TPACK as a continuum from disposition to situated action, mediated by perception under classroom complexity. Hofer and Grandgenett (2023) nested TPACK development inside institutional and technological affordance structures that constrain or enable individual growth.

A productive line of recent research distinguishes TPACK-as-knowledge from TPACK-as-practice. Koh and Chai (2024) found that preservice teachers could articulate TPACK-aligned rationales on surveys while underusing TCK and TPK in actual lesson plans. Tondeur et al. (2023) showed that peer-coached lesson planning produced stronger knowledge integration than individual reflection, suggesting that the social architecture of learning environments does not merely support TPACK development—it constitutes it. These findings reinforce the view that TPACK is not an individual cognitive asset accumulated incrementally but a relational, practice-embedded competence requiring social and disciplinary scaffolding.

Bandura (1997) identified self-efficacy beliefs—judgments about one's capacity to execute specific behaviors in specific contexts—as robust predictors of engagement, persistence, and performance. In educational technology research, technology integration self-efficacy correlates consistently with the frequency and sophistication of classroom technology use (Abbitt, 2011; Knezek & Christensen, 2016).

The relationship with TPACK is theoretically complex. Abbitt's (2011) early review documented positive associations, but left directionality unresolved. More recent work has unpacked the mechanism. Zelkowski et al. (2023), using simulated classrooms with AI-generated feedback, found that self-efficacy mediated the link between TPACK knowledge and observed lesson quality: at equivalent knowledge levels, more confident teachers produced more integrated lessons. Valtonen et al. (2024) extended this to problem-based learning, showing that self-efficacy gains trailed knowledge gains early in training but surged after authentic implementation experiences.

These patterns fit Bandura's (1997) theoretical emphasis on mastery experiences as the primary source of self-efficacy. Programs that limit technology training to observation, discussion, or decontextualized skill practice may build declarative TPACK while leaving confidence untouched, producing a competence-confidence gap that limits classroom transfer. That has direct implications for course sequencing and structure.

The professional development literature has converged on several design features that separate effective technology training from superficial exposure. Darling-Hammond et al. (2017) synthesized decades of evidence to identify six core principles: content focus, active learning, collaboration, modeling, coaching and expert support, and feedback and reflection. Subsequent work in educational technology has largely confirmed these while adding domain-specific nuance.

Extended duration is one of the better-documented predictors of TPACK transfer. Brief workshops produce short-lived knowledge gains that fade after posttest (Mouza & Karchmer-Klein, 2021). Semester-length programs that build progressively toward integrated TPACK yield more durable outcomes. Porras-Hernández and Salinas-Amescua (2022) documented this in a fifteen-week community-of-practice design, finding that PCK integration with technology deepened substantially in the final quarter—suggesting that TCK and TPK development may be prerequisites for meaningful TPACK synthesis.

Disciplinary grounding is a second, often neglected, design variable. Yeh et al. (2021) found that when preservice teachers worked within their content areas throughout a technology integration course—rather than with generic examples—gains in TCK and integrated TPACK were significantly larger. This aligns with Angeli and Valanides's (2013) argument that TPACK is a disciplinary competence, and that training designs which obscure disciplinary context may impede the very integration they aim to foster.

Collaborative and reflective structures have also proved essential. Tondeur et al. (2023) found that peer coaching and collaborative lesson-planning cycles outperformed individual reflection for TPACK gains, particularly in TPK and integrated TPACK. Dalal et al. (2021) documented the value of design-based tasks—iteratively developing, testing, and revising technology-integrated materials—in supporting TCK gains that persisted at six-week follow-up.

Table 1. Summary of TPACK Intervention Studies in Preservice Teacher Education (2021–2026)

Study	Sample	Intervention Type	Instrument	Key Finding	Journal
Blömeke et al. (2022)	$n = 148$	Microteaching + video reflection	TPACK Survey (adapted)	Significant gains in TK and TPK ($p < .01$)	Computers & Education
Dalal et al. (2021)	$n = 62$	Design-based TPACK modules (8 weeks)	Schmidt et al. (2009) scale	Large effect on TCK ($d = 0.79$)	JRTE
Hofer & Grandgenett (2023)	$n = 94$	Lesson study with EdTech tools	Mixed-methods TPACK survey	Moderate gains; TK strongest predictor	BJET
Koh & Chai (2024)	$n = 77$	Collaborative curriculum design tasks	Revised TPACK self-report	Significant PCK and TPACK gains ($p < .05$)	Teaching & Teacher Ed.
Mouza & Karchmer-Klein (2021)	$n = 89$	Field-based clinical experience + coaching	Observational + survey data	Gains in authentic technology application	Computers & Education

Study	Sample	Intervention Type	Instrument	Key Finding	Journal
Porras-Hernández & Salinas-Amescua (2022)	n = 41	Community of practice + reflection journals	Open-ended TPACK rubric	Qualitative depth in CK and PCK integration	JRTE
Tondeur et al. (2023)	n = 120	Peer coaching + digital lesson planning	Likert-scale TPACK + observation	Peer support mediated technology confidence	BJET
Valtonen et al. (2024)	n = 68	Problem-based learning with STEM tools	Hybrid TPACK + self-efficacy scale	TPK and TPACK gains (d = 0.65–0.82)	Teaching & Teacher Ed.
Yeh et al. (2021)	n = 55	Flipped classroom design practicum	Multiple TPACK subscales	Significant pre-post improvements across domains	Computers & Education
Zelkowski et al. (2023)	n = 84	Simulated classroom + AI feedback tools	TPACK + TISE scale (combined)	Self-efficacy and TPACK jointly predicted PD	BJET

Note. JRTE = Journal of Research on Technology in Education; BJET = British Journal of Educational Technology. Effect sizes (Cohen's d) reported where available. All studies used preservice teacher samples.

METHODS

We used a one-group pretest-posttest design (Campbell & Stanley, 1963) to examine changes in TPACK and self-efficacy across a 14-week course. The absence of a control group limits causal claims. Still, pre-experimental designs remain appropriate for initial evaluations of novel interventions in intact educational settings—particularly when the construct is theoretically expected to respond to structured learning (Fraenkel et al., 2019). We supplemented quantitative data with qualitative open-ended responses.

Fifty-five preservice teachers enrolled in a required undergraduate technology integration course at a mid-sized regional university in the southeastern United States. The course sat within the College of Education's teacher preparation program and was typically taken junior or senior year, after foundational coursework in learning theory and curriculum design. The sample included 38 women (69.1%) and 17 men (30.9%); mean age was 21.4 years (SD = 1.8). Disciplinary concentrations were elementary education (n = 22), secondary English language arts (n = 12), secondary mathematics (n = 11), and secondary social studies (n = 10). Prior technology experience varied: 29 participants (52.7%) had used classroom technology occasionally in field placements, 18 (32.7%) reported minimal exposure, and 8 (14.5%) reported moderate integration experience. Participation was voluntary and all participants provided informed consent. IRB approval preceded data collection.

The 14-week course, *Technology Integration in P–12 Classrooms*, was developed for this study in accordance with evidence-based principles for effective technology professional development (Darling-Hammond et al., 2017; Tondeur et al., 2023). It moved through four progressively integrated phases: (a) conceptual foundations (Weeks 1–2), building familiarity with the TPACK framework and foundational tools; (b) domain-specific technology development (Weeks 3–6), exploring content-area applications in discipline-specific subgroups; (c) integrated design and application (Weeks 7–11), collaborative planning and micro-teaching of technology-integrated lessons with peer and instructor feedback; and (d) field-based implementation and synthesis (Weeks 12–14), supervised implementation in field placements with structured reflection.

Active learning strategies ran throughout: design studios, lesson critique protocols, collaborative planning cycles, peer coaching dyads, and reflective journaling using structured TPACK observation prompts. Two practicing teachers recognized as district technology integration coaches served as practitioner consultants during design studio phases.

Table 2. Course Design and Data Collection Timeline

Phase	Activities & Data Collection Events
Weeks 1–2	Course orientation; TPACK conceptual framework; pretest administration (TPACK Survey + TISE Scale)
Weeks 3–4	Technology fundamentals; TK domain development; hands-on tool exploration labs
Weeks 5–6	Content-technology alignment; TCK workshops; subject-specific technology mapping
Week 7	Midpoint check-in; interim data collection (midpoint survey); peer feedback sessions
Weeks 8–9	Pedagogical design with technology; TPK focus; lesson plan critiques using SAMR/TPACK lenses
Weeks 10–11	Integrated design studios; collaborative TPACK lesson development; micro-teaching
Weeks 12–13	Field-based technology implementation; mentor observation cycles; reflective journaling
Week 14	Final presentations; posttest administration (TPACK Survey + TISE Scale); course synthesis

Note. TPACK Survey = adapted Schmidt et al. (2009) instrument; TISE = Technology Integration Self-Efficacy Scale. Bold weeks indicate formal data collection points.

TPACK Survey. We used an adapted version of Schmidt et al.'s (2009) instrument, a widely used self-report scale covering all seven TPACK domains. Adaptations followed Chai et al. (2013), adding four subject-area-specific items per domain and updating language to reflect contemporary digital tools. Responses used a 5-point Likert format (1 = strongly disagree, 5 = strongly agree). Internal consistency estimates for the current sample ranged from acceptable to strong (Cronbach's α = .77–.91).

Technology Integration Self-Efficacy Scale (TISE). We assessed self-efficacy with Browne's (2009) TISE, validated across preservice populations (Knezek & Christensen, 2016; Zelkowski et al., 2023). The 29-item scale uses a 5-point confidence scale and yields a total score. Internal consistency for this administration was α = .89.

Quantitative analysis proceeded in three stages. First, we computed descriptive statistics for all TPACK domains and TISE at pretest (Week 1), midpoint (Week 7), and posttest (Week 14). Second, we assessed normality of difference scores with Shapiro-Wilk tests; where violated, we used Wilcoxon signed-rank tests instead of paired t-tests. For normal distributions, we computed paired-samples t-tests. We estimated effect sizes with Cohen's d (paired), using thresholds of 0.20 (small), 0.50 (medium), and 0.80 (large) (Cohen, 1988). Significance was set at α = .05. All analyses ran in SPSS v. 27.

For qualitative analysis, two researchers independently coded a 30% subsample of open-ended posttest responses using reflexive thematic analysis (Braun & Clarke, 2022). Intercoder reliability was satisfactory (Cohen's κ = .82) before completing full coding. Themes were developed inductively and interpreted against existing literature.

RESULTS AND DISCUSSION

Descriptive Statistics

Table 2 presents means and standard deviations for all TPACK domains and TISE across the three time points. At pretest, overall TPACK means were moderate to moderately low, with the weakest scores in TPK (M = 3.18, SD = 0.79) and integrated TPACK (M = 3.09, SD = 0.86). CK was highest at pretest (M = 4.05, SD = 0.63), which was expected given prior disciplinary coursework. By posttest, all domains had increased meaningfully, with the largest raw gains in integrated TPACK (+1.05), TISE (+0.90), and TPK (+0.90).

Table 3. Descriptive Statistics: TPACK Domains and Technology Integration Self-Efficacy Across Three Time Points (N = 55)

Domain	Pre M	Pre SD	Wk7 M	Wk7 SD	Post M	Post SD	Gain	Effect d
Technology Knowledge (TK)	3.41	0.71	3.88	0.58	4.22	0.54	0.81	1.04
Content Knowledge (CK)	4.05	0.63	4.01	0.60	4.38	0.55	0.33	0.64
Pedagogical Knowledge (PK)	3.78	0.68	3.82	0.65	4.28	0.59	0.50	1.07
Pedagogical Content Knowledge (PCK)	3.62	0.74	3.71	0.69	4.19	0.62	0.57	1.12
Technological Content Knowledge (TCK)	3.25	0.82	3.39	0.77	4.01	0.64	0.76	1.39
Technological Pedagogical Knowledge (TPK)	3.18	0.79	3.27	0.74	4.08	0.67	0.90	1.50
TPACK (overall)	3.09	0.86	3.22	0.81	4.14	0.69	1.05	1.61
Technology Integration Self-Efficacy	3.31	0.77	3.44	0.71	4.21	0.65	0.90	1.53

Note. M = mean; SD = standard deviation. TISE = Technology Integration Self-Efficacy Scale. Gain = posttest minus pretest. Cohen's d computed for pretest-to-posttest differences. All items rated on 5-point scales.

Midpoint data revealed differential growth trajectories. CK and PK showed modest gains between pretest and midpoint (+0.33 and +0.50), suggesting that foundational knowledge in these domains was already partially developed and that early phases focused primarily on TK and initial TCK. TPK and integrated TPACK, by contrast, accelerated most sharply between midpoint and posttest, aligning temporally with the integrated design studio and field-based phases. This pattern is theoretically meaningful and is discussed below.

Inferential Statistics

Shapiro-Wilk tests indicated that difference scores for TK, CK, PK, and PCK were normally distributed ($p > .05$). For TCK, TPK, and integrated TPACK, normality was violated ($p < .05$), so we used Wilcoxon signed-rank tests; both parametric and nonparametric results converged. Table 3 reports the paired-samples t-test results.

Table 4. Paired-Samples t-Test Results: Pretest to Posttest Changes in TPACK Domains and Self-Efficacy (N = 55)

Domain	Mean Diff	SD Diff	t	df	p	Cohen's d	Sig.
Technology Knowledge (TK)	0.47	0.61	7.72	54	< .001	1.04	✓
Content Knowledge (CK)	0.33	0.58	4.77	54	< .001	0.64	✓
Pedagogical Knowledge (PK)	0.50	0.63	7.94	54	< .001	1.07	✓
Pedagogical Content Knowledge (PCK)	0.57	0.69	8.27	54	< .001	1.12	✓
Technological Content Knowledge (TCK)	0.76	0.74	10.30	54	< .001	1.39	✓
Technological Pedagogical Knowledge (TPK)	0.90	0.81	11.12	54	< .001	1.50	✓
TPACK (overall)	1.05	0.88	11.96	54	< .001	1.61	✓
Technology Integration Self-Efficacy	0.90	0.79	11.40	54	< .001	1.53	✓

Note. Mean Diff = posttest minus pretest. Wilcoxon signed-rank tests used for TCK, TPK, and TPACK (overall) due to non-normal distributions; z-values and effect sizes (r) reported in supplementary materials. Cohen's d thresholds: small ≥ 0.20, medium ≥ 0.50, large ≥ 0.80. Sig. ✓ = statistically significant at p < .001.

Every domain showed statistically significant pre-to-post gains (all $p < .001$). Effect sizes ran from moderate (CK: $d = 0.64$) to very large (integrated TPACK: $d = 1.61$). The largest effects clustered in integrated TPACK (d = 1.61), TPK (d = 1.50), and self-efficacy (d = 1.53)—precisely the domains and constructs most central to technology-pedagogy integration, rather than isolated technical skill or content mastery. TK also showed a large effect (d = 1.04), notable given the course's early emphasis on foundational fluency.

CK showed the smallest gain (0.33) and effect size (d = 0.64), which was expected: disciplinary subject matter knowledge develops primarily through content coursework and field experience, not through technology integration training specifically. The stability of CK across time points (M = 4.05 at pretest, 4.01 at midpoint, 4.38 at posttest) suggests the course supported participants in leveraging existing content knowledge through technological tools rather than extending content mastery itself.

Tabel 5. Pre- and Post-Course TPACK Domain Scores Comparison (N = 55)

Domain	Pretest M	Posttest M	Relative Gain (Scale 1–5)
TK	3.41	**4.22**	+0.81 (24% increase)
CK	4.05	**4.38**	+0.33 (8% increase)
PK	3.78	**4.28**	+0.50 (13% increase)
PCK	3.62	**4.19**	+0.57 (16% increase)
TCK	3.25	**4.01**	+0.76 (23% increase)
TPK	3.18	**4.08**	+0.90 (28% increase)
TPACK	3.09	**4.14**	+1.05 (34% increase)
TISE	3.31	**4.21**	+0.90 (27% increase)

Note. Values represent group means on a 5-point scale. TISE = Technology Integration Self-Efficacy Scale.

Qualitative Findings: Open-Ended Response Themes

Analysis of 55 posttest open-ended responses generated four primary themes.

Theme 1: Practical Relevance. The most frequently coded theme concerned participants' sense that course activities connected directly to classrooms they had observed or would soon enter. Many contrasted this course favorably with prior technology coursework they described as tool-focused but not teaching-focused. Participants found the disciplinary design studios transformative because they required justifying technology choices on pedagogical and content-specific grounds rather than on novelty or availability.

Theme 2: Collaborative Inquiry. Participants across concentrations described peer-based learning as among the most productive elements. Peer coaching dyads and cross-disciplinary design critiques were frequently cited as contexts where participants confronted assumptions about their own TCK and TPK that solo reflection had not surfaced. Several described moments of genuine conceptual challenge during peer feedback as pivotal experiences that catalyzed TPACK integration differently from instructor-delivered content.

Theme 3: Reflective Growth. Approximately half of participants identified reflective journaling with structured TPACK prompts as a practice that helped make explicit knowledge that had previously been tacit. Several described a shift over the semester from viewing technology as an add-on to viewing it as a representational and communicative medium with discipline-specific affordances and constraints. This language mirrors TPACK's theoretical vocabulary, suggesting that conceptual enculturation into the framework supported metacognitive development.

Theme 4: Disciplinary Grounding. Secondary education participants in particular valued working within disciplinary subgroups during domain-specific technology development. Mathematics preservice teachers discussed GeoGebra, Desmos, and dynamic geometry environments as tools they now understood through TCK frames rather than merely as computational aids. ELA participants described multimodal composing and digital annotation tools in similarly discipline-anchored terms. These accounts support the quantitative finding that TCK showed among the largest effect sizes, and underscore the argument that disciplinary grounding is constitutive rather than supplementary.

These findings make several contributions to the literature on TPACK development in preservice education. Across all TPACK domains and self-efficacy, participants demonstrated significant, practically meaningful growth over 14 weeks, with effect sizes notably larger than those reported in many shorter-duration or less structurally integrated interventions (Dalal et al., 2021; Tondeur et al., 2023). The concentration of largest gains in TPK, integrated TPACK, and TISE is theoretically interpretable in ways that advance understanding of how TPACK develops.

The large effect size for TPK ($d = 1.50$) is perhaps the most substantively important finding. TPK has historically been among the weakest TPACK components in preservice populations, largely because it requires understanding how technology restructures pedagogical relationships, pacing, differentiation, and assessment—not merely knowing how tools function. The course's emphasis on integrated design tasks, where technology choices required pedagogical justification, peer critique, and revision based on student-centered rationales, appears to have created productive conditions for TPK growth. This fits Tondeur et al.'s (2023) finding that peer coaching cycles are particularly effective for TPK, and Koh and Chai's (2024) argument that TPK requires social negotiation rather than individual acquisition.

The magnitude of self-efficacy gains ($d = 1.53$) is equally striking. Zelkowski et al. (2023) and Valtonen et al. (2024) both documented self-efficacy gains in technology integration PD, but neither achieved effect sizes this large in preservice populations. The accelerated growth between midpoint and posttest—coinciding with field-based implementation—aligns directly with Bandura's (1997) theoretical primacy of mastery experiences. Participants who successfully implemented technology-integrated lessons in real K–12 classrooms, with structured support from cooperating teachers and university supervisors, experienced the form of direct performance success most predictive of durable confidence. This has direct implications for program design: self-efficacy development may require authentic implementation, not merely course-based practice, and programs without supported, technology-integrated field placements may systematically underinvest in this dimension.

The differential growth trajectory is also theoretically informative. Early-phase stability of CK and late-phase acceleration of TPK and integrated TPACK suggest a sequential rather than parallel pattern: foundational TK development precedes and enables TCK, which in turn supports meaningful TPK and TPACK integration. This progression mirrors TPACK's conceptual architecture, where integrated knowledge is theoretically downstream of domain-specific knowledge, but it has not previously been documented as a temporal trajectory within a single semester with multiple measurement points. Future studies with denser measurement could explore this sequence more precisely.

The qualitative findings deepen these interpretations. The prevalence of disciplinary grounding among secondary participants, and its association with TCK development, reinforces Angeli and Valanides's (2013) argument that TPACK cannot be taught generically. When preservice mathematics teachers worked with Desmos and GeoGebra not as computational conveniences but as representational tools embodying epistemological commitments about how mathematical relationships can be explored and visualized, they developed a form of content-technology knowledge that is irreducibly disciplinary. Similarly, the collaborative inquiry theme's emphasis on peer critique as a site of conceptual challenge resonates with Vygotskian accounts in which the zone of proximal development activates through socially mediated, discursively challenging interaction rather than solo processing.

Several limitations warrant acknowledgment. The pre-experimental design precludes causal attribution: gains could reflect maturation, history effects, or other coterminous factors. The sample, while adequate analytically, came from a single institution, limiting generalizability. Self-report TPACK instruments capture perceived rather than demonstrated knowledge; the relationship between survey scores and observed instructional behavior, while positive, is moderate (Archambault & Barnett, 2010). Future research should incorporate performance-based assessments, observation protocols, and longitudinal follow-up into the first year of teaching to examine whether course-based gains persist under independent teaching conditions.

Despite these constraints, the findings contribute meaningfully to the evidence base on effective preservice technology integration design. The convergence of quantitative effect sizes with qualitative accounts of mechanisms strengthens the interpretation that extended duration, disciplinary grounding, collaborative structures, authentic implementation, and structured reflection are empirically consequential for TPACK and self-efficacy—not merely pedagogically interesting.

CONCLUSION

We examined TPACK development and technology integration self-efficacy change among 55 preservice teachers across a 14-week course designed around current evidence on effective technology professional development. Significant pre-to-post gains emerged across all TPACK domains and self-efficacy, with the largest effects for integrated TPACK, TPK, and self-efficacy. Qualitative data identified disciplinary grounding, collaborative inquiry, practical relevance, and reflective practice as primary mechanisms participants credited for their growth.

These findings carry implications for program design. First, technology integration courses should be structured around disciplinary coherence rather than generic tool literacy; tool exposure cannot substitute for content-embedded technology reasoning. Second, self-efficacy development requires authentic implementation experience, not merely simulation, and programs without supported technology-integrated field placements should expect deficits in this dimension. Third, collaborative and reflective structures are integral mechanisms of TPACK development, particularly for TPK and integrated TPACK—the components most predictive of effective classroom technology use.

The pre-experimental design limits causal inference, and future research should address this through quasi-experimental or randomized designs, denser measurement schedules to document growth trajectories, and longitudinal follow-up into early teaching. Accumulating such evidence is essential for moving the field from theoretical advocacy to empirically grounded program design that demonstrably prepares teachers for the technologically complex classrooms they will enter.

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